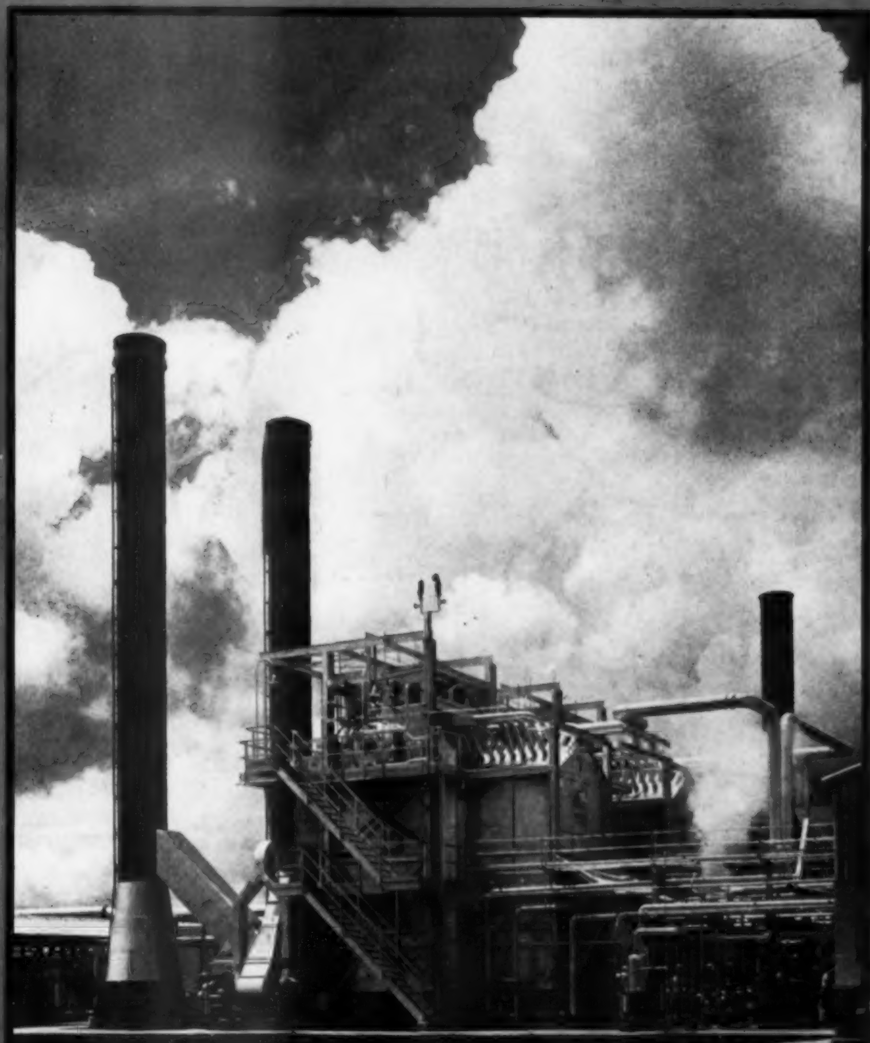
COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

RR

November, 1950



Outdoor boiler plant of Salamanca Refinery, Mexico

165,000-kw Added to Richmond Station

Treatment of Cooling Water

Quick Starting of Steam Turbines

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COMBUSTION

Editorials

Survey Indicates Ample Power

The eighth semi-annual survey of the nation's power capacity, including the open facilities of manufacturers of heavy power equipment, has just been released by the Edison Electric Institute. The conclusions reached, in view of the rate at which new capacity is going into service, are that there will be ample power to meet all demands, even though the reserve margin at this year's winter peak is likely to be slightly under that of last year. Only in the Southeast and the western part of the Pacific Northwest are there indications of insufficient reserve, although extensive interconnections with adjacent areas should offset this deficiency.

More than six and a half million kilowatts will have been added during the current year and nearly 22 million kilowatts in the next three years. So far the Korean situation does not appear to have significantly affected the demand.

The survey has indicated that the equipment manufacturers have ample open capacity for a substantial increase in schedules over the next two or three years, although this may be tempered by the materials situation and such governmental controls as are likely to be evoked.

Despite this assurance from a source that has access to reliable information, certain groups in Washington spearheaded by Interior Secretary Oscar L. Chapman, maintain that the present and planned private utility expansion will be insufficient to meet prospective demands of the defense program, involving greatly increased production of aluminum, magnesium and indicated atomic energy demands, when these are added to the ever increasing domestic and industrial demand.

However, as has been pointed out previously in these pages, peak demands in an emergency, based on wartime experience are not likely to be as great as might be expected, in view of three-shift production and curtailment of non-essential services.

Research and Engineering Education

One may conceive of engineering education in terms of three intermingling streams, one concerned with imparting fundamental technical information, another dealing with inculcation of citizenship responsibility, and a third having to do with extending engineering horizons through research. Though the ever-increasing amount of technical knowledge tends to obscure the manner in which engineering progress is achieved, it is important that the qualities of an inquiring mind be developed in the course of engineering education. Research is a significant means toward this end, and therefore the Engineering Research Council of the American Society for Engineering Education is to be commended for its preparation of an informative booklet entitled "Research Is Learning."

Obviously, it is not possible for more than a small percentage of engineering students to engage in formal research as a life-long career. But it is essential that at some time during his training the student engineer learn something of the thinking and the reasoning that underlies the creative work responsible for engineering advances. Thus fundamental research in which the student can take an active part at the college level is highly desirable.

The results of college engineering research are made known not only through the specific findings of individual projects but also through the training of students. As is stated in "Research Is Learning," "The thinking of one teacher, germinating in his own group of students, moves on to industry and to other schools to influence still more engineers."

Research has another benefit. By studying through existing information to the point of reaching the frontier of new knowledge, the engineering student finds that he is dependent upon specialists in other fields, thereby learning the value of collaborating with other technically trained men. This is an important educational objective that has tangible value in professional practice.

The Power Show

With orders for new power plant construction at an all-time high and further plans being formulated for the next two and three years, the time is most propitious for the biennial Power Show which will be held at the Grand Central Palace, New York, November 27 through December 2, concurrently with the Annual Meeting of the A.S.M.E. Moreover, although this will be the nineteenth show, it will be the first to be officially sponsored by the A.S.M.E.

Current design trends stress not only improved efficiency, but also labor saving in the form of more automatic devices and remote controls—all aimed at reducing operating expense to help offset high fuel and labor costs. Also, the nationwide awakening of interest in control of atmospheric pollution assures a large audience for exhibits in that category. These are but a few lines to be featured; among the products of more than three hundred exhibitors, one is certain to find many that will well repay the time spent in the visit.

165,000-Kw Addition to Richmond Station at Philadelphia

By J. H. HARLOW

Mechanical Engineer, Philadelphia Electric Co.

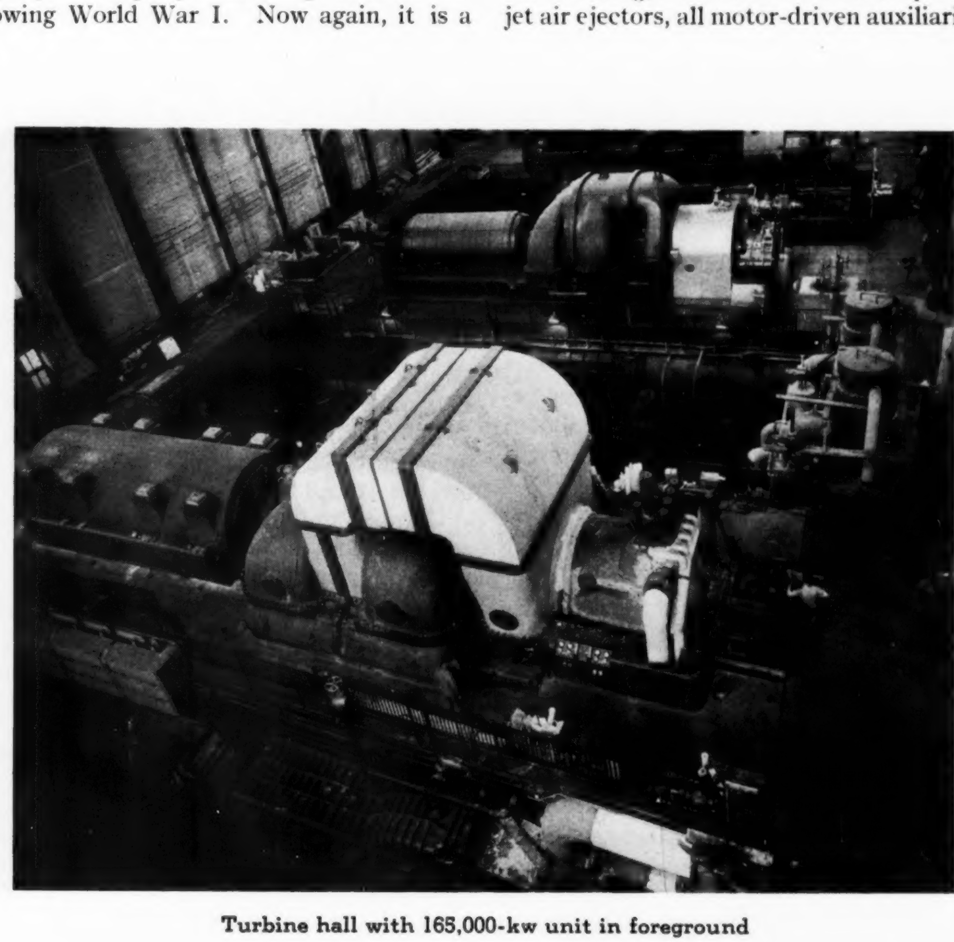
This extension to Richmond Station of Philadelphia Electric Company raises its total capacity to 450,000 kw. The history of the station is reviewed, and the engineering considerations leading to selection of new conditions are given. The 165,000-kw unit is supplied with steam at 1250 psig, 950 F by two 800,000-lb per hr pulverized-coal or oil-fired steam generating units. Boiler feed pumps are of the re-entry type.

RICHMOND Station of the Philadelphia Electric Company was projected in the early 1920's as a part of the Company's expansion program which was made necessary by the rapidly increasing demands for electricity following World War I. Now again, it is a vital part of the expansion program which has been made necessary by a similar increase in demand for electricity which is occurring following World War II. During the intervening twenty-five years, many developments that have come into being can be highlighted by a comparison of the then and now installations.

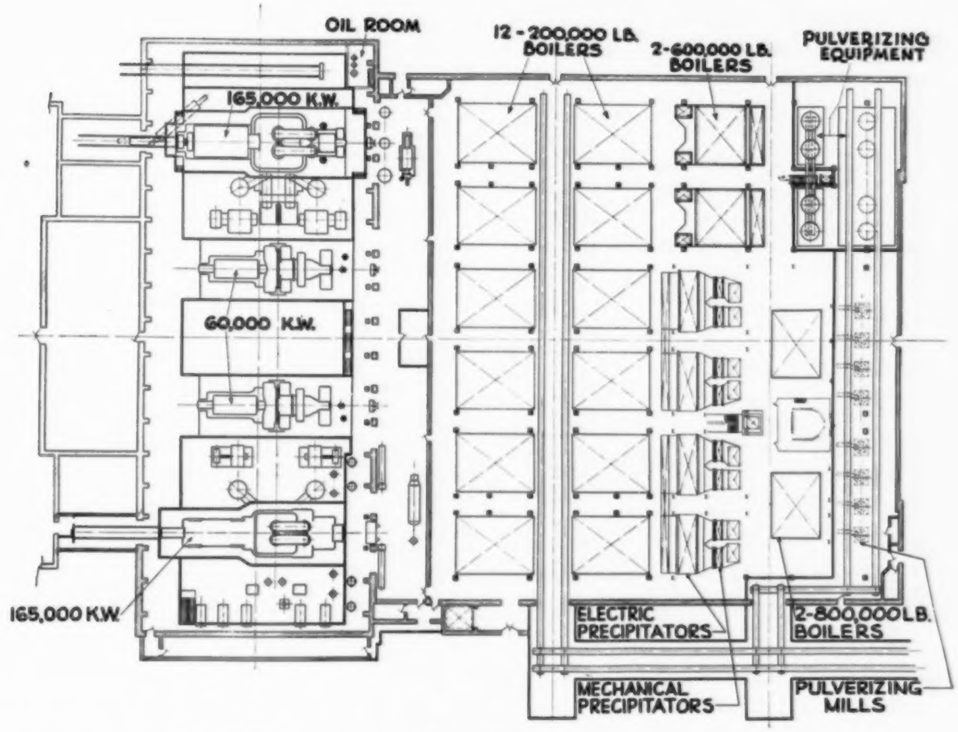
With this latest addition, Richmond becomes the largest plant on P.E. system having a total capacity of 450,000 kw, comprised of two 60,000-kw units and two 165,000-kw units.

The station first went into service late in 1925 with one 50,000-kw turbine-generator which was followed by a second identical machine in early 1926. These were tandem-compound, 1800-rpm, General Electric machines. Steam for these two units was supplied by twelve Sterling bent-tube, stoker-fired boilers.

The station included many forward-looking features. Among these were water-cooled furnace walls, tubular air preheaters, regenerative heat cycle with four stages of feed heating, deaerator and makeup evaporator, steam jet air ejectors, all motor-driven auxiliaries, unit auxiliary



Turbine hall with 165,000-kw unit in foreground



Plan of boiler house and turbine hall showing 1925, 1935 and 1950 installations

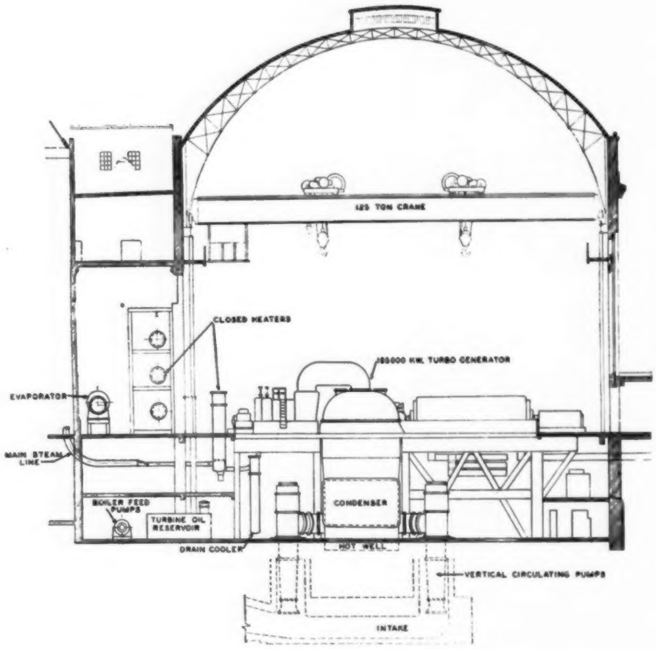
transformers and stub bus, emergency house generator, and station bus phase isolation. Along with the station, there were installed a step-up substation and four of the very early runs of 66,000-volt underground cable, together with Kenetron cable-testing equipment. The throttle steam conditions were selected to be 400 psig and 675 F, and the feedwater temperature at full load was about 300 F.

From the start this was an extremely successful installation. The water walls minimized stoker troubles, particularly side-wall and bridge-wall clinkers, which were then so common. The tubular air preheaters which developed an air temperature of about 250 F were very successful, and the annual boiler efficiency approximated 88 per cent. The feedwater heating system and auxiliary arrangement proved entirely satisfactory and the 50,000-kw turbine-generators were soon found to be conservatively designed and were re-rated at 60,000 kw. The yearly heat rate of this station during the period when these were the only units was about 13,500 Btu per net kwhr, a fair rate to compare even with today's designs.

The original concept of the ultimate development of Richmond Station comprised three buildings; each to house four 50,000-kw units and twenty-four stoker-fired boilers. It was planned that the first two turbine-generators, numbered 10 and 11 because of their position in the ultimate scheme, would be followed quickly by the installation of units numbered 9 and 12 which would complete the occupancy of number 3 building. However, two circumstances arose which prevented this plan from materializing. First, the Philadelphia Electric Company entered upon the development of the Conowingo hydro-electric project of 252,000 kw on the Susquehanna River which was completed in 1928; and second, before the load had increased to the point of absorbing this large block of capacity, the depression of the 1930's had begun.

Nevertheless, early in the 1930's it was determined that an addition would be made to Richmond Station. This addition was designed to take advantage of major advances in the art of power plant design which had occurred since the 1925 project was placed in service. The most notable change was in the capacity of the unit which could be accommodated. That is, when the 1925 project was being planned, the largest unit which it was considered feasible to build was 50,000 kw; when the additional capacity was being studied about 1933, it was found to be practical to build a unit of 165,000 kw for installation in the building space originally provided for one 50,000-kw unit. Pulverized-coal firing, by this time, had obtained wide acceptance and its use made it possible to obtain boilers in sizes commensurate with the size of the larger turbine-generator and which could be made to fit within the existing building walls. Although the turbine required approximately 1,500,000 lb of throttle steam per hour for full load, only two boilers, each rated at 600,000 lb per hr, were initially installed, thus limiting the capacity of the machine to about 135,000 kw. The steam pressure was selected at 400 psig to match the earlier installation, and the steam temperature 825 F, which was about as high as reasonably could be considered at that time. With a desuperheater, placed in the tie between the two steps of construction, it is possible to operate the entire plant in a completely integrated manner. A bin arrangement was installed for the pulverized coal system, and hydraulic couplings were used for draft control and for boiler-feed pressure control. The turbine-generator was manufactured by Westinghouse and the boilers and pulverizers by Babcock & Wilcox.

This installation, completed in 1935, has been very successful and in several of the fifteen years since its initial operation, the turbine-generator, although limited



Cross-section through turbine hall

to 135,000 kw by boiler capacity, has produced in excess of one billion kilowatt-hours. It has justified, in many ways, the faith and confidence of the Philadelphia Electric Company executives who undertook its construction during a period of depression and when reserve requirements were more than amply satisfied.

Following the installation of No. 12, as the 1935 unit at Richmond is called, construction moved to other sites, and approximately 700,000 kw of capacity was placed in operation at other locations before it became desirable again to add to the capacity of the Richmond plant.

When system development studies indicated the need for increased system capacity and that the Richmond site was the proper location, studies were undertaken to determine the proper size of unit and the preferred steam conditions. In regard to size, 165,000 kw appeared to be a natural selection for the following reasons:

Selection of Unit Capacity

(*a*) The plant already housed a 165,000 kw turbine-generator. Thus the local reserve requirements would not be altered.

(*b*) This would be the fourth unit of approximately this size on the Philadelphia Electric System.

(*c*) A unit of this size would be as large as could be installed readily in the location.

(*d*) An investigation of the possibility of installing two 100,000 kw, 3600-rpm units as an alternate did not prove to be practical.

(*e*) A unit of similar size was already under contract by another utility so that engineering and design time should be greatly reduced and the selection of a unit of this size provided an opportunity to duplicate and thereby to comply in principle with the idea of standardization.

In regard to steam conditions, 1250 psig and 950 F were selected because:

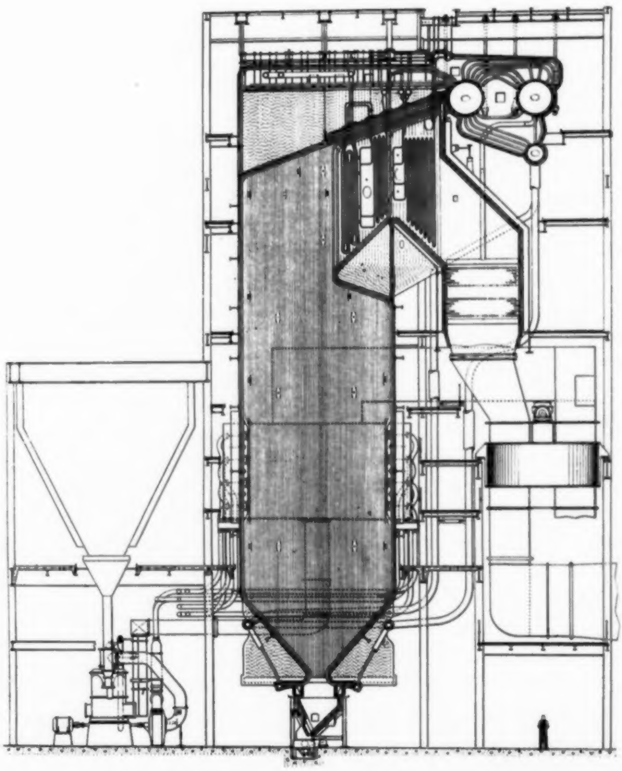
(*a*) Our economic studies indicated these conditions to be optimum for this location.

(*b*) The size of the turbine-generator and the availability of the space in the existing building indicated a two-boiler installation. Reheat, therefore, did not appear to be desirable.

(*c*) These steam conditions, together with the size item mentioned previously, conform in principle with the idea of standardization.

The new turbine-generator for Richmond Station, known as No. 9 because of its location in the original plan, is a General Electric, 1800-rpm tandem-compound unit of 165,000 kw capability. The high-pressure turbine contains two rows of impulse blading and eighteen rows of Rateau blading. The low-pressure turbine is double flow with four Rateau stages in each flow path. The generator is hydrogen cooled and is designed for 165,000 kw at 0.9 power factor with $^1/_2$ lb hydrogen pressure. Steam is supplied by two Combustion Engineering-Superheater, Inc., boilers, each of 800,000 lb per hr capacity; and the turbine exhaust is condensed by an Ingersoll-Rand condenser of 75,000 sq ft and condensate is returned through a dual feedwater heating system as illustrated in the simplified schematic drawing. Feedwater is heated to 457 F before being supplied to the boilers.

The parallel feedwater system has these advantages: (1) It results in the elimination of individual heater bypasses with a consequent large reduction in the number of valves usually associated with a regenerative cycle because each row of heaters can provide the bypass for the other when needed. (2) It results in obtaining a negligible loss in efficiency when it is necessary to bypass. (3) With a turbine-generator of this size, the heaters, if placed in a single row, become so large as to be very expensive to manufacture, and investigations indicated that it was cheaper to build two smaller stage heaters to

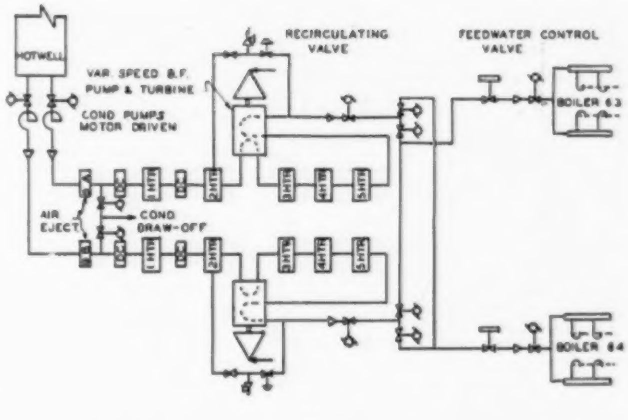


Section through 800,000-lb per hr steam generating unit

operate in parallel than to build one large enough to accommodate the entire flow. The low-pressure heaters, Nos. 1 and 2, with their associated independent drain coolers are arranged vertically. The intermediate pressure heaters, Nos. 3, 4 and 5, contain integral drain coolers and are arranged in a horizontal position. The heater exchangers have tubes of the U-bend type eliminating the need for internal floating heads and are all equipped with Admiralty-A metal tubes, except the highest pressure heater which has 70-30 cupro-nickel tubes.

Features of Re-entry Feed Pump

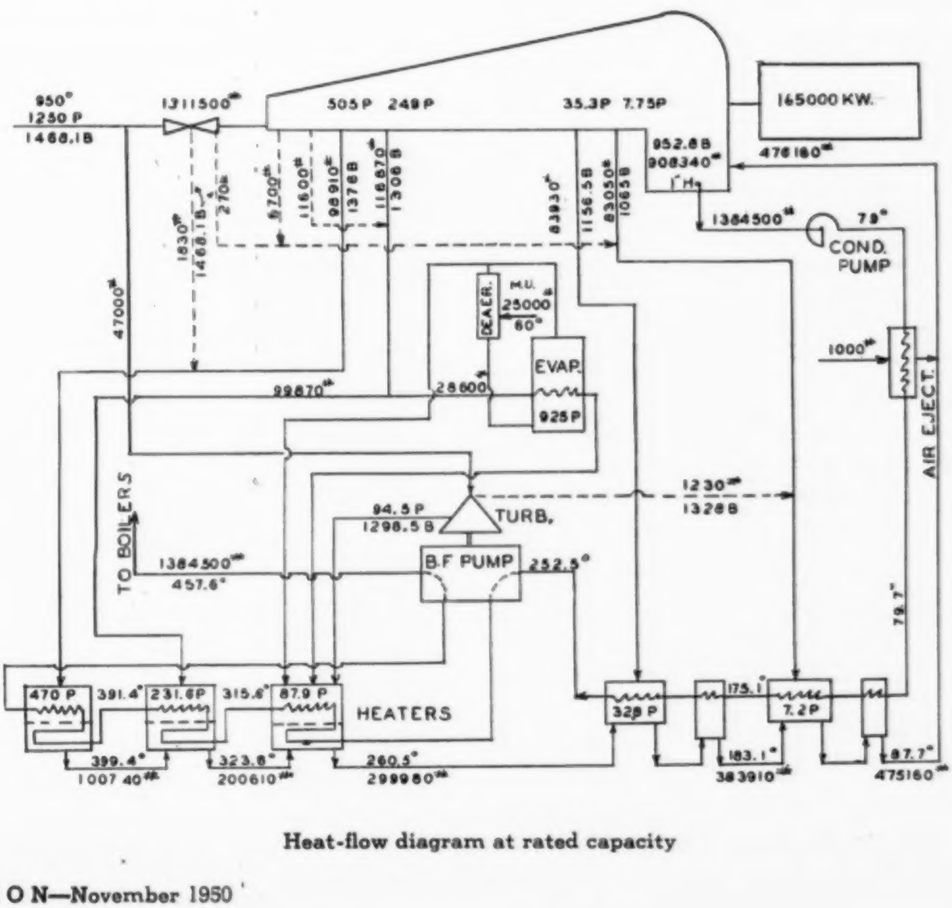
Each line of feedwater heaters contains a condensate pump and a re-entry boiler-feed pump supplied by Byron-Jackson. The condensate pump, with an outlet pressure of 240 psig, discharges through the air ejector inter- and after-condensers and the two low-pressure heaters and drain coolers to the suction of the low-pressure element of a re-entry boiler-feed pump. The low-pressure element of the re-entry feed pump, in turn, discharges through the three intermediate pressure heaters to the suction of the high-pressure element of the same pump which delivers directly to the boilers. The re-entry boiler-feed pumps are turbine driven with a normal full load speed of 4200 rpm when operating in parallel. They are designed to be operated in excess of 5000 rpm in the event of failure of one, thus increasing the output of the remaining pump so that the effect of the loss is minimized. The loss of a pump, thus results in a reduction in main unit capacity of only about 40,000 kw because of this arrangement. Regulation of the boiler-feed pumps is by an excess pressure controller, and flow



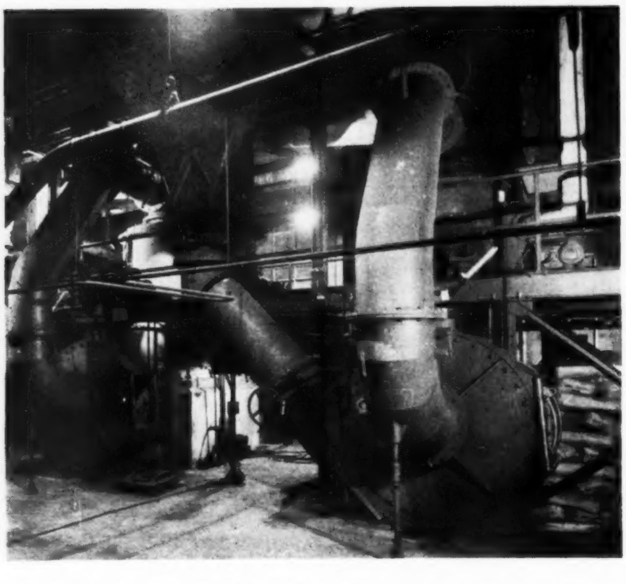
Schematic diagram of feedwater system

to each boiler is maintained by a three-element feedwater regulator operating on one feedwater valve.

The re-entry boiler-feed pump is of particular interest. Heretofore, it has been the Philadelphia Electric practice to use a booster pump about midway in the heater system and a boiler-feed pump at the end of the heater system, thus minimizing the pressure on the various stage heaters. An objection to such an arrangement is the multiplicity of units with their consequent increased number of service connections, whether electric or steam. With the re-entry pump there is created, in effect, a booster pump and a boiler-feed pump within the confines of dimensions normally associated with a single boiler-feed pump. With the arrangement that has been provided at Richmond, the two elements of the pump



Heat-flow diagram at rated capacity



Pulverizers for one boiler, with exhauster fans in foreground

always work in series so that there can be no unbalance between the amount of water pumped by the cooler lower pressure element and the hotter high-pressure element. In this installation the re-entry pump is entirely satisfactory. It is driven by a Westinghouse turbine which operates under the same throttle steam conditions as the main turbine, and exhausts into the third-stage feedwater heater. The normal speed of the boiler-feed pump and its turbine drive was selected at 4200 rpm because of the gain in efficiency obtainable as compared to a 3600-rpm pump. Use of a steam-turbine drive has the advantage of not limiting the selection of the optimum speed for the turbine-pump combination as would be the case with motor drive. Also, because the turbine can operate at variable speeds, it provides an efficient method for feedwater pressure regulation and for increasing capacity in emergency.

An evaporator, which is fed with treated softened river water, is installed in the feedwater heating cycle for makeup. The condenser is arranged with a reheating and deaerating integral hotwell of approximately 15,000 gal capacity. With this arrangement no other provision has been made in the feedwater cycle for deaeration or surge capacity. Two condensate storage tanks of 100,-000 gal aggregate capacity are provided, and in circumstances where makeup is required to maintain the level in the condenser hotwell a makeup valve will open automatically and admit condensate at rates up to 750,000 lb per hr to the condenser. A draw-off line is similarly provided to make possible the automatic removal of excess water from the condenser hotwell to storage tanks.

Each of the two Combustion Engineering-Superheater, boilers is supplied by four C-E Raymond bowl mills with exhausters and is equipped with superheater, economizer, two regenerative air preheaters and mechanical and electrical dust collectors. Two Sturtevant forced-draft fans and two Sturtevant induced-draft fans serve each boiler, all with inlet vane control.

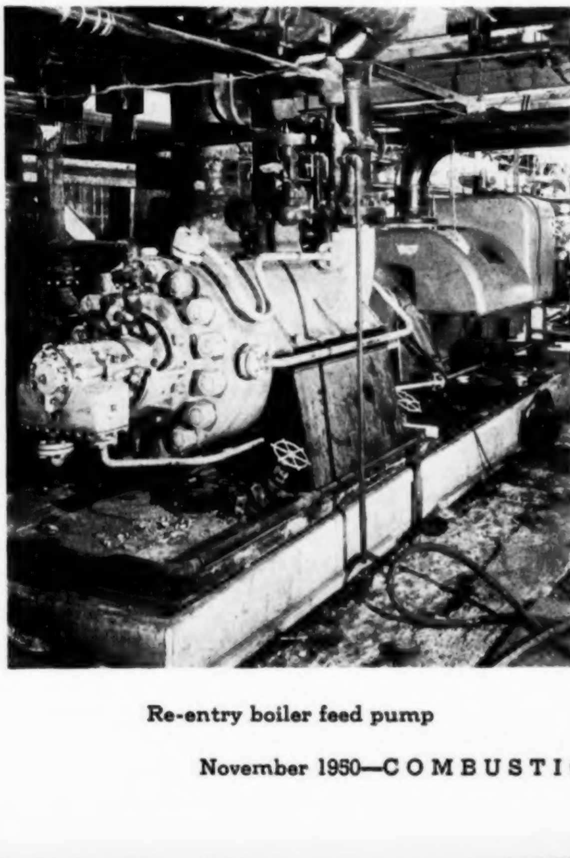
As indicated in one of the accompanying illustrations, the boilers are of the radiant type with open-pass dry-bottom furnaces arranged for tangential firing with the burners tilted automatically for steam temperature control. The water-wall tubes are 3 in. outside diameter and on $3^1/_8$-in. centers to provide a heating surface of 36,510 sq ft and a volume of 60,000 cu ft. On this basis, at the full rated capacity of 800,000 lb per hr, the furnace heat release will be 15,450 Btu per cu ft per hr, or 95,200 Btu per sq ft per hr effective projected radiant surface. Under these design conditions it is calculated that the gas temperature entering the first steam generating tube bank will be approximately 1960 F. This is felt to be a conservative value and should result in a minimum of slagging difficulty.

The Raymond bowl mills have a nominal capacity of 23,800 lb per hr when pulverizing 55 Hardgrove grindability coal to 70 per cent through 200 mesh, the mill and exhauster being driven by a 250-hp motor. Each mill supplies one burner in each of the four corners of the furnace, there being a total of sixteen burners. In addition to the pulverized coal burners, there are three oil burners in each corner of the furnace. These burners also tilt for steam temperature control and are sufficient in number to allow for full load operation on oil.

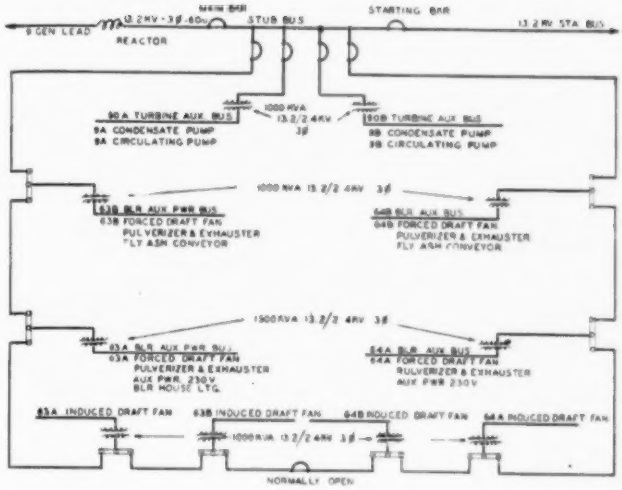
The superheater contains 32,400 sq ft of $2^1/_8$-in. outside diameter tubing and is designed to produce a steam temperature of 950 F. It is in a pendant arrangement with primary and secondary banks between which a spray desuperheater is installed to limit the outlet temperature of the steam. Since steam temperature control will normally be accomplished by adjusting the tilt of the burners the spray device is a safety measure.

The economizer contains 22,655 sq ft of 2-in. outside diameter tubes, and the two Ljungstrom air preheaters each have a surface of 98,200 sq ft with $76^1/_2$-in. elements. Outlet gas temperature at normal load is anticipated to be 324 F and preheated air temperature 634 F. Each boiler is provided with Diamond retractable steam lances.

As Richmond Station is located within the limits of the City of Philadelphia, particular attention was given to



Re-entry boiler feed pump



Schematic diagram of electric auxiliary supply system

the problem of reducing the amount of dust emission from the stacks. To this end each boiler has been equipped with an American Blower type mechanical dust collector having a rated efficiency of 80 per cent, and a Research Corporation electrostatic precipitator having a rated efficiency of 80 per cent, thus resulting in a combined efficiency of 96 per cent. Both of these collectors are connected to an American Blower dust transport system with drop-out cyclones and dust storage tanks.

The dry ash collected in the furnace hopper is transported pneumatically to other storage tanks by a United Conveyor system. For disposal the dust and the dry furnace ash is passed through dustless unloaders and conditioned for delivery to railroad cars. An accompanying photograph shows the dust and dry ash tanks and the spouts from the dustless unloaders.

One stack has been provided for the two boilers. This is 15 ft in diameter and contains an exhaust nozzle designed to accelerate the emitting gases to 95 ft per sec velocity when both boilers are operating at full load.

The boiler control boards are located in an air-conditioned room between the two boilers. These boards contain a Leeds & Northrup electrical combustion control, together with the regular complement draft gages, pressure gages, switches, etc., as required for operation. The turbine control board is located adjacent to the head end of the turbine, and the boiler feed and heat cycle control board is near the boiler feed pumps.

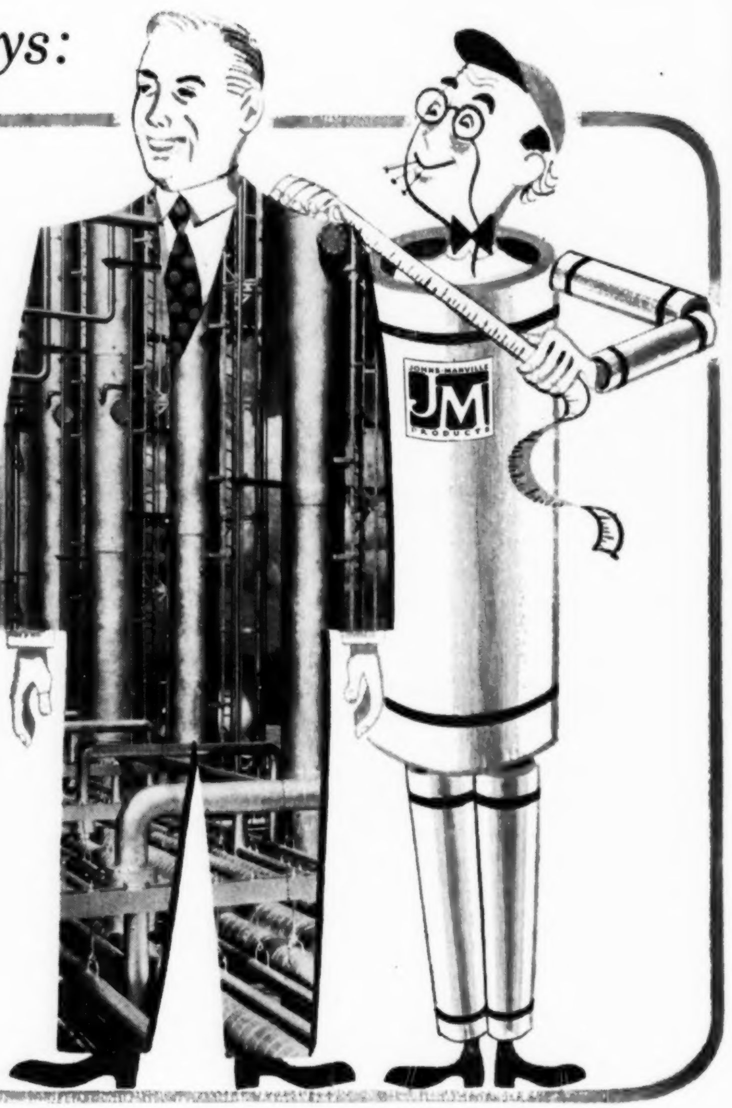
All auxiliaries, with the exception of the boiler-feed pumps, are motor-driven and are supplied from a stub bus which is normally connected to the generator leads but can be connected to the station bus for starting or emergency. A schematic single line diagram of the system is included, and it will be noted that it comprises a 13,200-volt loop through various areas of the power house. This loop is tapped at various load centers in order to feed a step-down transformer at that center. There are ten such load centers in all. There are two in the turbine plant for circulating and condensate pumps and four for each boiler, two of which are for pulverizers and forced draft fans and two for induced draft fans. The loop is capable of being opened at various locations, and if a fault develops the affected run can be isolated and the remaining cable placed back in service.

The generator is a two-winding machine rated at 165,000 kw, 0.9 power factor, 13,200 volts, 3 phase. The windings are paralleled and supply two 13.2/70 kv, 100,000 kva, 3-phase step-up transformers for direct connection to the 66-kv bulk power transmission system of the Company. Generator leads are encased in metal runs for phase isolation.

Engineering, preparation of plans and purchase of all apparatus and equipment have been carried out by Philadelphia Electric Company. Construction has been done by United Engineers and Constructors, Inc., under the general supervision of the Company's Engineering Department.

Fly-ash tanks and dust-unloading building; hydro-bin system and slag disposal in foreground

Mr. Insulation says:



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Treatment of Cooling Water

By S. B. APPLEBAUM

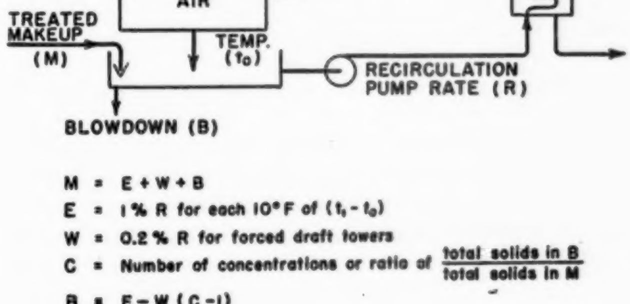
Manager of Cold Process Div., Cochrane Corp.

Following descriptions of the once-through and the recirculating systems, with comments on their adaptability to given conditions, the text takes up deposits and their treatment, comparison of different treatments, capacity calculations, and concludes with typical cases involving an acid-treatment plant and lime-acid treatment.

MODERN industry uses increasing quantities of water for cooling purposes to carry away the heat generated in plant processes as for example in steam power plant condensers, oil refinery heat-exchangers and condenser boxes, ammonia condensers, steel-plant blast furnace tuyeres, air conditioning equipment and diesel engine cooling jackets. The total amount of cooling water used has been estimated as well over a billion gallons of water per minute for all industry. An ample supply of cooling water is usually one of the prime factors that determine plant location.

Once-Through and Open and Closed Recirculating Systems

Where the plant is relatively small or the available water supply large, a "once-through" cooling system is preferred. With this the cooling water is wasted. It is not only more economical to install but usually involves less difficulty from corrosion or deposits in the heat-absorbing system. However, the growth of industry has been so rapid that shortages in water supply have become a major problem in many parts of the country. For example, in New York City, "once-through" systems for air-conditioning in buildings are being limited today.



$M = E + W + B$

E = 1% R for each 10°F of $(t_1 - t_0)$

W = 0.2% R for forced draft towers

C = Number of concentrations or ratio of $\frac{\text{total solids in B}}{\text{total solids in M}}$

$$B = \frac{E - W(C-1)}{C-1}$$

Fig. 1—Diagram of open recirculating system

Consequently, open recirculating cooling systems are being installed more and more, using spray ponds or cooling towers to release the heat to the atmosphere by evaporation of a portion of the cooling water; see Fig. 1. This system saves water because the warm water from the condensers or heat-exchangers after being cooled through the cooling tower is re-used. The only loss is the small part evaporated and carried away by wind plus that wasted by blowdown.

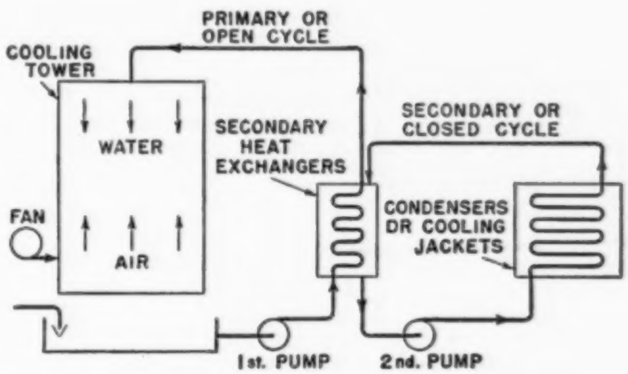


Fig. 2—Double, or closed, recirculating system

However, open recirculating cooling systems not only involve the installation of the cooling tower and pumps but usually also some type of water treatment to prevent corrosion and deposits. This is because evaporation results in a concentration of the dissolved and suspended solids present in the makeup similar to concentration build-up in boilers. It increases the amount of such impurities several times (usually 2 to 10 times) and thereby increases their deposition. Also, the cooling tower introduces an aerating effect which often increases the dissolved oxygen content and thereby stimulates corrosion.

Where the raw water available contains excessively high total solids or is very limited in amount, closed or double recirculating cooling systems are installed. In such systems the primary water that absorbs heat from the plant equipment is kept in a closed cycle not exposed to the atmosphere. This warm water is, in turn, cooled by the secondary recirculating water stream through a heat-exchanger. The second water stream is cooled in a cooling tower; see Fig. 2. This double recirculating system avoids evaporation and concentration in the first

water stream. The makeup for the first stream is therefore negligible, and condensate or zeolite-treated water, or demineralized water, may be employed to prevent deposits in the condensers. Chromate may be added to avoid corrosion. However, this double system is more expensive to install because of the large secondary heat-exchangers and pumps required. Also the bad water used in the second stream causes deposits in these secondary heat-exchangers. Consequently, the great mass of recirculating systems are of the open type, for which reason this article will deal principally with water treatment methods designed for such open systems.

Increased Costs Due to Corrosion and Deposits in Cooling Systems

Plant managers are keenly aware of these increased costs because plant maintenance problems and operating costs in general are increased when corrosion or deposits are experienced. Such increased costs are due to:

1. Increased outages for shutdown to clean the equipment. This reduces productive capacity.
2. Investment in spare equipment to avoid long outage periods.
3. Reduced efficiencies in steam turbines and similar equipment when condenser vacuums suffer due to deposits.
4. Impaired quality of some manufactured products when the cooling effluent temperatures rise due to deposits.
5. Increased pumping costs due to the greater power required to overcome increased friction or pressure loss due to deposits in pipe lines and other passageways.

TABLE I

DEPOSITS
CAUSES AND TREATMENT

	Constituent in Deposit	Caused by following Impurities in Water	Method of Treatment
1.	Mud	Suspended solids	a) Coagulation b) Settling c) Filtration
2.	Slime	Algae, diatoms, bacteria, protozoa, fungi, molds, etc	a) chlorination b) addition of copper sulfate, sodium penta-chlorphenates or other chemicals acting as fungicides and bactericides
3.	Oily or greasy	Oil due to contamination	a) coagulation and filtration
4.	Calcium carbonate	Calcium and bicarbonate ions	a) addition of acid b) lime treatment c) sodium zeolite d) addition of "sequestering" reagents such as hexa-meta-phosphate for "threshold treatment", addition of scale inhibitors such as tannins, glucosates, various colloids, organic compounds and surface active agents
5.	Calcium sulfate	Calcium and sulfate ions	a) reduction of calcium by lime or soda ash b) reduction of sulfates by various compounds c) addition of reagents in (4) d) increased blowoff
6.	Magnesium silicate	Magnesium ions and silica	a) reduction of magnesium by lime b) reduction of silica by ferric hydroxide or magnesium oxide or hydroxide c) Addition of reagents as in (4)
7.	Magnesium hydroxide	Magnesium ions	Reduction of magnesium by lime
8.	Silica	High silica in raw water	Reduction of silica by methods given in (6)
9.	Iron oxides or hydroxides	Iron ions, also iron bacteria	aeration, settling, filtration, also sterilization of bacteria

TABLE 2

CORROSION
CAUSES AND TREATMENT

Factors Causing Corrosion	Methods of Treatment
Low pH or acid in water	Raise pH value by adding an alkali such as lime or soda ash
Micro-biological - certain sulfate reducing bacteria	sterilization or addition of bactericides
Dissolved carbon dioxide	Aeration plus raising pH value by addition of alkali
Sulfur dioxide gas due to waste gases around the cooling tower	Chlorination
Dissolved oxygen	1) Vacuum deaerator on suction side of recirculating pump 2) Addition of chromates 3) Addition of chemicals such as hexa-meta-phosphates and various nitrogenous organic compounds to render the metal surfaces passive by microscopic films. 4) Maintenance of controlled thin protective calcium carbonate films by control of Langelier Saturation Index (S. I.)

6. Replacement of tubes and other vital parts that are damaged by corrosion.
7. Cost of labor for cleaning equipment to remove the deposits.

Kinds of Deposits, Their Cause and Treatment

It is of value to classify the various deposits because the type of water treatment is determined by the nature of the main constituents of the deposit. Table 1 gives such a classification.

A given deposit will contain many of these constituents together; hence a combination of some of the treatment methods mentioned are usually required.

Factors Causing Corrosion and Treatment Methods

In Table 2 are given the factors that are responsible for corrosion and the various methods of treatment that are available.

Often water treatment to prevent deposits may keep the heat-exchanging metallic surfaces so clean that the dissolved gases can then attack the metal, in which case prevention of deposits and corrosion are closely tied together and really constitute two phases of the same water treatment problem. This is especially true of the controlled scale method where the water must be so treated that excessive supersaturation is avoided in order to prevent heavy deposits yet it must be left slightly supersaturated so that a thin scale will deposit and act as a protective film against corrosion from dissolved gases.

Data Required for Selection of Water-Treatment Method to Prevent Deposits

In Table 1 a number of alternate treatment methods are listed for deposit prevention. In most cases selection of the method cannot wait until the cooling system is placed in operation and analysis has been made of the deposits formed. The usual procedure is to collect all the pertinent facts regarding a proposed cooling system and select the water-treatment method accordingly. These pertinent facts are:

1. Type of cooling tower, probable windage losses, temperature drop from inlet to outlet of the

cooling tower, rate of recirculation in gallons per minute and other data to permit calculation of the water-treatment plant capacity.

2. Range of chemical analyses of the raw water at different seasons of the year, including physical impurities such as turbidity or suspended solids, color, etc.
3. Field data regarding the source of supply—well, spring, lake or river—and whether trade waste or sewage contamination are to be expected.
4. Range of temperature rise from inlet to outlet of the various condensers, heat-exchangers and coolers and description of these units, including kind of metal used for the shell and tubes.
5. Is the supply of makeup unlimited or is the water scarce or expensive?
6. Skill of the operating personnel available which may determine the type of water-treatment plant to be preferred.

Calculation of Capacity with Recirculating Systems

The capacity of the water-treatment plant must be sufficient to provide for evaporation from the tower (E); windage losses (W); and blowdown (B) to control the number of concentrations (C).

Fig. 1 shows the usual recirculating system and gives the formula for calculating B after determining E, W and C. The value of C depends on the chemical analyses of the raw and treated makeup water, temperature of the heat-exchanger effluent (t_1) and the Langelier Saturation Index selected for the concentrated recirculating water.

Calculation of Langelier Saturation Index

The laws governing deposition of calcium carbonate on heat-exchanging surfaces have been studied by many chemists both here and abroad. In this country Prof. W. F. Langelier has made outstanding contributions in this field (1) (2).* The chemical reaction involved is simple:

$$\underset{\text{Calcium bicarbonate}}{Ca(HCO_3)_2} + \text{heat} = \underset{\text{Calcium carbonate,}}{CaCO_3} + CO_2 + H_2O$$

The solubility of calcium carbonate is quite low, usually only 1 to 3 grains per gallon (17–51 ppm) depending on temperature and the amount of other constituents in the water. If the amount of calcium carbonate present in the concentrated recirculating water exceeds this solubility, the water is "supersaturated" and calcium carbonate will deposit. If the reverse is true, the water is "undersaturated" and may be corrosive if dissolved oxygen is present.

This can be demonstrated by the "marble test." In this test, after determining the pH of the water, an excess of marble or powdered limestone is added and stirred in the water for several hours. The water is then filtered and its pH determined again. If the pH has decreased, some calcium carbonate has been deposited on the marble due to supersaturation. If the pH has increased, some marble has been dissolved due to undersaturation. The change of pH by this test gives some idea of the amount of "super" or "under" saturation but it is hard to carry out, especially at the actual heat-exchanger effluent temperature involved.

To expedite control, Langelier developed a usable formula for the theoretical saturation pH value (pH_s) at which the water would be in chemical balance, neither depositing or attacking marble. Then the actual pH value (pH_a) of the water is measured (at room temperatures) and the difference between the two pH values ($pH_a - pH_s$) is the Langelier Saturation Index. If it is positive the water will usually deposit. If it is negative it will usually be aggressive.

The Langelier formula (as expressed by Larson and Buswell) (3) for the saturation pH (pH_s) is:

$$pH_s = p\,Ca + p\,Alk\,M + C_t$$

where

p Ca = The negative logarithm of the Ca ion present, expressed in mols per liter

p Alk M = The negative logarithm of the methyl orange alkalinity in equivalents per liter

C_t = A constant depending on the total dissolved solids present and the temperature

Acid treatment which does not reduce the Ca must reduce the alkalinity much more. When the Ca is reduced as by lime treatment or by zeolite, the alkalinity does not have to be reduced as much as when acid is used alone for any desired (p Ca + p Alk).

Since p Ca and p Alk are logarithms they can be added in this manner. This additive logarithmic sum corresponds to the well-known solubility or activity product:

$$(Ca^{++}) \times (CO_3^{--}) = K \text{ (a constant)}$$

In other words as Ca goes up, the CO_3 must go down or vice versa, when the system reaches equilibrium.

Fig. 3 shows this expressed graphically and gives the values of Ca^{++} and CO_3^{--} (both expressed as $CaCO_3$) that may be expected at room temperatures after cold lime treatment in a well-designed sludge contact reactor.

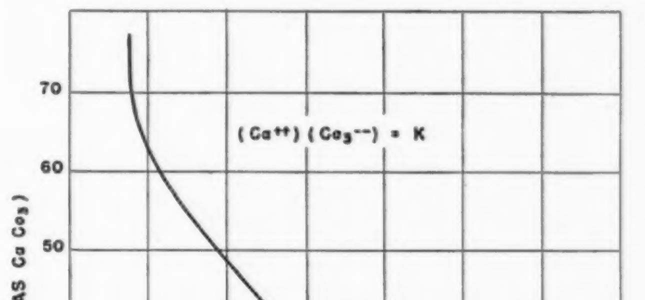


Fig. 3—Curve of Ca^{++} vs. CO_3, as obtained from sludge contact reactor in cold-lime treatment

* Figures in parentheses refer to References at end of article.

Limitations in Use of Langelier Index

The Langelier Index is not applicable with accuracy where the water analysis falls outside the following approximate limits:

(*a*) Total solids up to 2000 ppm.
(*b*) pH range—6.0 to 10.0.
(*c*) Hardness—above 50 ppm.
(*d*) Alkalinity up to 1000 ppm.
(*e*) Temperatures up to 170 F.

Furthermore, as Prof. Langelier has pointed out (6): "The saturation index is not a value determined from a sample of water taken from one point in a water system which can be applied to the same water at another point in the system after its character has been modified through deposition or corrosion . . . ."

Therefore, it is necessary to sample the water at the point where knowledge of the activity (corrosion or deposition) is desired.

The Saturation Index ($pH_a - pH_s$) is a measure of directional tendency and driving force but not of capacity, i.e., it does not indicate how much calcium carbonate will deposit. For example, if the water is very low in Ca, as in zeolite effluents, the Index may be positive and high and yet there may be no appreciable deposit.

Furthermore, the actual pH value (pH_a) is determined at room temperatures in the laboratory for convenience and this room temperature is obviously lower than the actual temperature (t_1) of effluent of the condenser or heat-exchanger at the point where deposition or corrosion may take place. Since pH_a is affected by temperature an error is introduced. If the cooling water effluent temperature is the same in all the condensers and heat-exchangers in a given system, then this error can be compensated by selecting a given saturation index for the system which by experience prevents too thick a scale. This index range is usually +0.5 to +1.5 but in most cases it lies between +0.5 to +1.0.

However, if some heat-exchangers in a system discharge the cooling water at a higher temperature than other exchangers, then the hotter water may make too thick scale and the cooler water no scale.

Suggestions for Uniformity

S. T. Powell (4, 5, 7) has suggested some additional procedures to ensure greater uniformity of scaling even when the effluent temperatures range from 80 to 150 F. in different exchangers in the same system. He selects a certain optimum actual pH value (pH_a) (at 80 F) depending on the alkalinity so that both pH_a and pH_s decrease with temperature at about the same rate. This assures greater uniformity of scaling at the hotter as well as the cooler surfaces. Then based on experience or observation of pilot heat-exchangers, a Saturation Index (S. I.) is selected that will control the thickness of this uniform scale. The S. I. selected is controlled by water treatment to change the Ca and alkalinity and yet maintain the optimum pH_a above selected as closely as possible. This usually results in much higher pH_a values and Ca than were previously customary, and may therefore be justified only for extreme cases of high differences in temperature (of say 70 F or from 80 to 150 F.) in the effluent cooling water from the different heat-exchangers in a system. In most cases the range of the different effluent temperatures is under about 30 to 40 deg F and this of itself avoids too non-uniform a scaling even when employing the conventional Langelier Saturation Index methods.

Comparison of Various Treatment Methods to Control $CaCO_3$ Deposit

As Table 1 indicates, aside from the addition of "sequestering" and other reagents to the recirculating stream to inhibit crystalline scale formation, there are three main external methods of treating the makeup water to control the thickness of $CaCO_3$ scale protective films; these are

1. Addition of acid alone.
2. Lime treatment followed by acid.
3. Sodium zeolite plus some hard water bypassed, followed in some cases by acid.

Acid Treatment

In this process acid alone is added to reduce the alkalinity, converting the bicarbonates to sulfates; thus:

$$\underset{\text{Calcium bicarbonate}}{Ca(HCO_3)_2} + \underset{\text{Sulfuric acid}}{H_2SO_4} = \underset{\text{Calcium sulfate}}{CaSO_4} + \underset{\text{Carbon dioxide}}{2CO_2} + \underset{\text{water}}{2H_2O}$$

As the previous discussion showed, this decrease in the alkalinity increases the pH_s and thereby reduces the S. I. (saturation index) to limit the scale formed. However, the alkalinity must be reduced to lower limits because the calcium is not reduced. Consequently, this process requires skill in its control to avoid the danger of overfeeding acid which would acidify the water and tend to cause corrosion.

This method is usually confined to clear iron-free well waters because suspended matter and iron also causes deposits and acid treatment would not avoid them. It is also limited to waters that do not contain excessive sulfates. The acid treatment increases the sulfates corresponding to the alkalinity reduced and, therefore, the total sulfates in the concentrated recirculating water might exceed the solubility of calcium sulfate which would cause sulfate deposits.

Where conditions are suitable this process has the following advantages:

(*a*) Low investment cost.
(*b*) Low operating cost where acid is cheap, as at points located near the acid manufacturing plants.
(*c*) No precipitate is formed and therefore no settling or clarification equipment is required to separate this precipitate from the water. Also, no disposal of calcium carbonate sludge is involved. With lime treatment this disposal of sludge sometimes presents a problem where no adequate sewer or river is available to receive such sludge. In such cases, lime sludge must be lagooned in a low spot where it is dried in the sun and then periodically carted away. In other cases, the sludge is centrifuged, dried and reburnt to form quick lime to be used over again. Several large muncipalities reburn their lime sludge from lime softening plants in that manner.

Case I—Acid Treatment

This, a typical acid-treatment plant, is a public utility in the Southwest operating with 650-psi boilers and five condensing turbine-generators totaling about 30,000 kw. The water supply comes from three wells. It is hard, high in solids but clear and plentiful. There is, therefore, ample supply available for cooling tower blowoff and consequently the concentrations can be kept low, almost like a once-through system. An acid feed proved the most economical treatment of the cooling tower makeup under these conditions, particularly since there was inadequate space available for a lime treatment plant which would have saved blowoff water.

There are three cooling towers at this plant, handling a total of 46,000 gpm of recirculating cooling water. The temperature leaving the surface condensers and entering the towers is 95 F, and that of the water leaving the towers is about 79 F.

The loss of water by evaporation, $E = 0.1\% \times (95 - 79) = 1.6\%$

$E = 1.6\% \times 46{,}000$ gpm $= 736$ gpm

The windage loss (W) is 0.2% $= 92$ gpm

The blowoff (B) to maintain 1.5 (C) concentrations which is necessary to avoid $CaSO_4$ precipitation due to the high sulfates present is:

$$B = \frac{E - W(C - 1)}{C - 1}$$

$$= \frac{736 - 92\,(1.5 - 1)}{1.5 - 1}$$

$$= \frac{736 - 46}{0.5} = 1380 \text{ gpm}$$

Total $= 2208$ gpm

Table 3 gives the analysis of the raw water, acid-treated water, and the concentrated recirculating water. The

CASE NO. 1 — OPERATING RESULTS SHEET — TABLE 3

Name: Public Utility in South — Date:

Address:

Identification: A) Well water; B) After acid treatment; C) After 1.5 concentrations

	Constituent		Analysis in PPM as	A	B	C	D	E
Cations	Calcium	(Ca^{++})	$CaCO_3$	398	398	597		
Cations	Magnesium	(Mg^{++})	$CaCO_3$	275	275	412		
Cations	Sodium	(Na^{+})	$CaCO_3$	531	531	797		
Cations	Hydrogen = FMA	(H^{+})	$CaCO_3$					
Cations			$CaCO_3$					
Total Cations			$CaCO_3$	1204	1204	1806		
Anions	Bicarbonate	(HCO_3^{-})	$CaCO_3$	184	30	45		
Anions	Carbonate	(CO_3^{--})	$CaCO_3$	0	0	0		
Anions	Hydroxide	(OH^{-})	$CaCO_3$	0	0	0		
Anions	Sulfate	(SO_4^{--})	$CaCO_3$	771	925	1388		
Anions	Chloride	(Cl^{-})	$CaCO_3$	249	249	373		
Anions			$CaCO_3$					
Total Anions			$CaCO_3$	1204	1204	1806		
Total Hardness			$CaCO_3$	673	673	1009		
Methyl Orange Alkalinity			$CaCO_3$	184	30	45		
Iron, Total			Fe					
Carbon Dioxide, Free			CO_2	4.6	136	0		
Silica			SiO_2	14	14	21		
Turbidity								
Total Dissolved Solids								
pH				7.3	5.6	7.4		
pH_s						8.3		
Langelier Index						+0.9		

Operating Cost

Chemicals	lbs. per 1000 gal.	* Chemical cost cents per lb.	Chemical cost—cents per 1000 gallons
Sulphuric Acid	1.4	1.5	2.1

alkalinity is reduced from 184 to 30 ppm and the sulfates correspondingly increased. Thus after 1.5 concentrations the alkalinity is kept below 50 ppm which with a positive Langelier index of 0.9 prevents $CaCO_3$ deposition in the condensers. The acid-feed diagram is shown in Fig. 4.

The acid is stored in a large horizontal steel cylindrical tank filled from acid tank cars by applying compressed air. This strong acid then flows by gravity into a small measuring tank that holds a day's supply. An orifice meter with contactor is located on each makeup water line to the cooling towers. This makes a contact every 30 sec at full flow. When the contact is established it

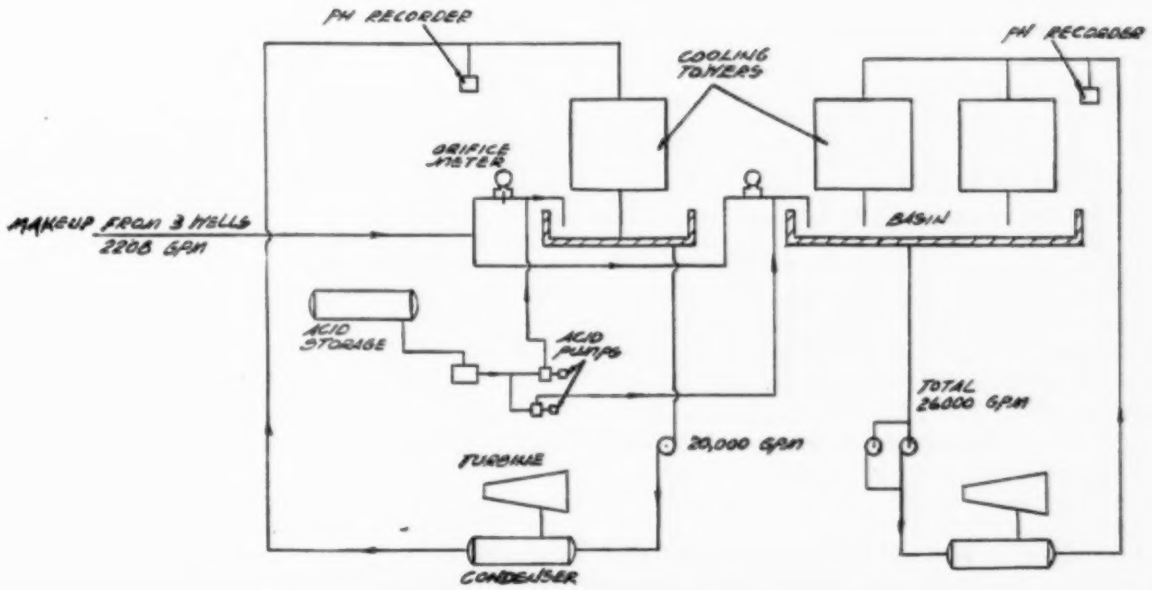


Fig. 4—Diagram for acid feed, Case 1

starts a motor-driven reciprocating strong-acid pump, of 8.5 gph capacity, which pumps a measured amount of acid into the makeup line. A reset adjustable microflex timer controls the duration of pumping and stops the acid pump which then awaits the next meter contact.

A pH Recorder is located on each recirculating line to record the pH of the water entering the cooling towers to check the Langelier Index. However, this does not control the acid feed.

In other plants the acid is pumped directly into the basin under the cooling tower where it is mixed with the makeup water in a baffled open trough. This avoids possibility of corrosion of the makeup line between the point of entrance of the acid and the basin but it requires location of the acid feed near the basin.

The reciprocating acid pump has a manual stroke adjustment which permits changing the amount of acid fed. Also, the reset timer is adjustable and duration of the pumping period can be changed easily which also changes the amount of acid fed. Thus two simple adjustments of the acid dosage are available.

By pumping strong acid (66 deg Bé) the acid storage tank and acid piping can be made of steel, unlined because steel resists strong acid.

pH Controlled Acid Feeds

More and more acid feeds are pH controlled to insure proper results without so much attention. The pH meter and controller measures the pH of the treated water and controls the speed of the motor driving the acid pump through a "Thymotrol." This is satisfactory if the raw water flow rate is not too variable. For variable rates a double control is recommended. A meter with potentiometer controls the motor speed through a Thymotrol and the pH controller changes the stroke of the pump through a reversible motor.

Such pH controlled feeds usually require a flywheel type of agitation to mix the acid and water in an open basin. This is advisable to avoid pH hunting of the control. The agitation basin should hold several minutes' supply and the agitator should be of the high-speed type or be of the recirculating pump type that will turn over the contents of the basin several times a minute. This will produce a treated water of very constant pH value without hunting.

Lime-Acid Treatment

In this method both the alkalinity is reduced and the calcium is selectively removed. Magnesium is not appreciably reduced because magnesium carbonate is soluble and does not give deposit difficulty. The reactions are:

$$\underset{\text{Calcium bicarbonate}}{Ca(HCO_3)_2} + \underset{\text{Calcium hydrate lime}}{Ca(OH)_2} = \underset{\text{Calcium carbonate precipitate}}{2CaCO_3} + \underset{\text{water}}{2H_2O}$$

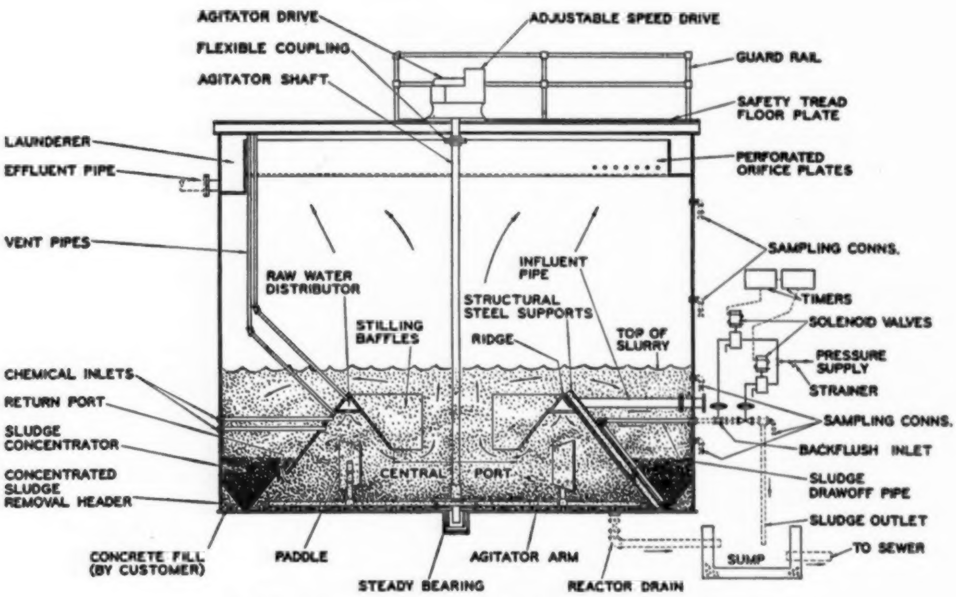


Fig. 5—Cochrane liquon sludge contact reactor

Some of the calcium carbonate is soluble; not all precipitates. Therefore, acid is added to convert this residual soluble calcium carbonate to sulfate and bicarbonate. Thus:

$$\underset{\text{Calcium carbonate}}{2CaCO_3} + \underset{\text{Sulfuric acid}}{H_2SO_4} = \underset{\text{Calcium bicarbonate}}{Ca(HCO_3)_2} + \underset{\text{Calcium sulfate}}{CaSO_4} + \underset{\text{Carbonic acid}}{H_2CO_3}$$

To avoid magnesium reduction by lime and to obtain the maximum calcium reduction without adding excessive amounts of lime, the use of a modern Sludge Contact or Solids Contact Reactor is customary. This Reactor is illustrated in Fig. 5.

This Reactor embodies several improvements:

(*a*) It combines in one package unit the agitation of the chemicals and water and previously accumulated sludge in suspension in the mixing zone together with separation of the sludge from the treated water in the clarifying zone above it.

(*b*) The agitator operates over the entire bottom of the unit avoiding any possibility of deposit on the bottom.

CASE II

OPERATING RESULTS SHEET

Table 4

Name Ohio Public Utility   Date

Address

Identification:
A) Raw well
B) After aerator
C) After lime and alum
D) After acid
E) After 4 concentrations

	Constituent		Analysis in PPM as	A	B	C	D	E
Cations	Calcium	(Ca^{++})	$CaCO_3$	280	280	91	91	364
Cations	Magnesium	(Mg^{++})	$CaCO_3$	140	140	126	126	504
Cations	Sodium	(Na^{+})	$CaCO_3$	300	300	300	300	1200
Cations	Hydrogen = FMA	(H^{+})	$CaCO_3$					
Cations			$CaCO_3$					
Total Cations			$CaCO_3$	720	720	517	517	2068
Anions	Bicarbonate	(HCO_3^{-})	$CaCO_3$	246	248	0	17	68
Anions	Carbonate	(CO_3^{--})	$CaCO_3$	0	0	35	0	0
Anions	Hydroxide	(OH^{-})	$CaCO_3$	0	0	0	0	0
Anions	Sulfate	(SO_4^{--})	$CaCO_3$	400	400	410	428	1712
Anions	Chloride	(Cl^{-})	$CaCO_3$	72	72	72	72	268
Anions			$CaCO_3$					
Total Anions			$CaCO_3$	720	720	51[illegible]	517	2066
Total Hardness			$CaCO_3$	420	420	217	217	866
Methyl Orange Alkalinity			$CaCO_3$	246	248	35	17	6[illegible]
Iron, Total			Fe	12	6	0	0	0
Carbon Dioxide, Free			CO_2	2[illegible]	8	0	0	0
Silica			SiO_2					
Turbidity						5 to 7	3 to 6	
Total Dissolved Solids								
pH				7.0	7.9	10.4	8.3	8.3
pH_s								7.5
Langelier Index								+0.8

OPERATING COST

Chemicals	lbs. per 1000 gal.	* Chemical cost cents per lb	Chemical cost—cents per 1000 gallons
Lime Hydrate	1.9	0.8	1.5
Alum	0.17	1.5	0.3
Acid	0.16	1.5	0.3
			2.1

* Based on best available information. Check local supply sources.

(*c*) The baffles separate the mixing from the clarifying zones and thus prevent the agitation from disturbing the efficient separation of precipitates from the water.

(*d*) These baffles have two ports, a larger one, the central port through which the mixed water and sludge rises into the clarifying zone and the other, the smaller circumferential port through which sludge returns to the mixing zone to enrich its sludge strength. The water travels radially from the central port to the collecting trough at the top. This avoids upward passage of the water through the sludge blanket around the central port and thus avoids sludge carryover.

(*e*) The entire top area of the Reactor is available for sludge separation because none of the baffles project up into the clarifying zone. This reduces the size of the tank to a minimum.

(*f*) A large sludge concentrator is provided at the periphery at the bottom which concentrates the sludge several times, thereby reducing the amount of water wasted to the sewer to a minimum.

Case II—Lime-Acid Treatment

This illustrates a typical case where lime and acid is added to treat a hard well water. Table 4 gives the analyses of the raw and treated water at various stages of treatment and the operating cost.

This plant is used for the treatment of the cooling water makeup in a public utility plant in Ohio, handling 1600 gpm. The water is first aerated to reduce the CO_2 and thus save lime; also to oxidize the dissolved iron. The water then enters the Reactor where the lime and alum are added to reduce the calcium and the alkalinity. Acid is added to the settled water in the clear well alongside the Reactor.

A portion of the effluent is filtered and passed through a sodium zeolite plant to finish the softening of the water ahead of evaporators to keep them scale-free. Part of the softened water is also used for general sanitary service in the station.

Fig. 6 shows how the treatment is applied.

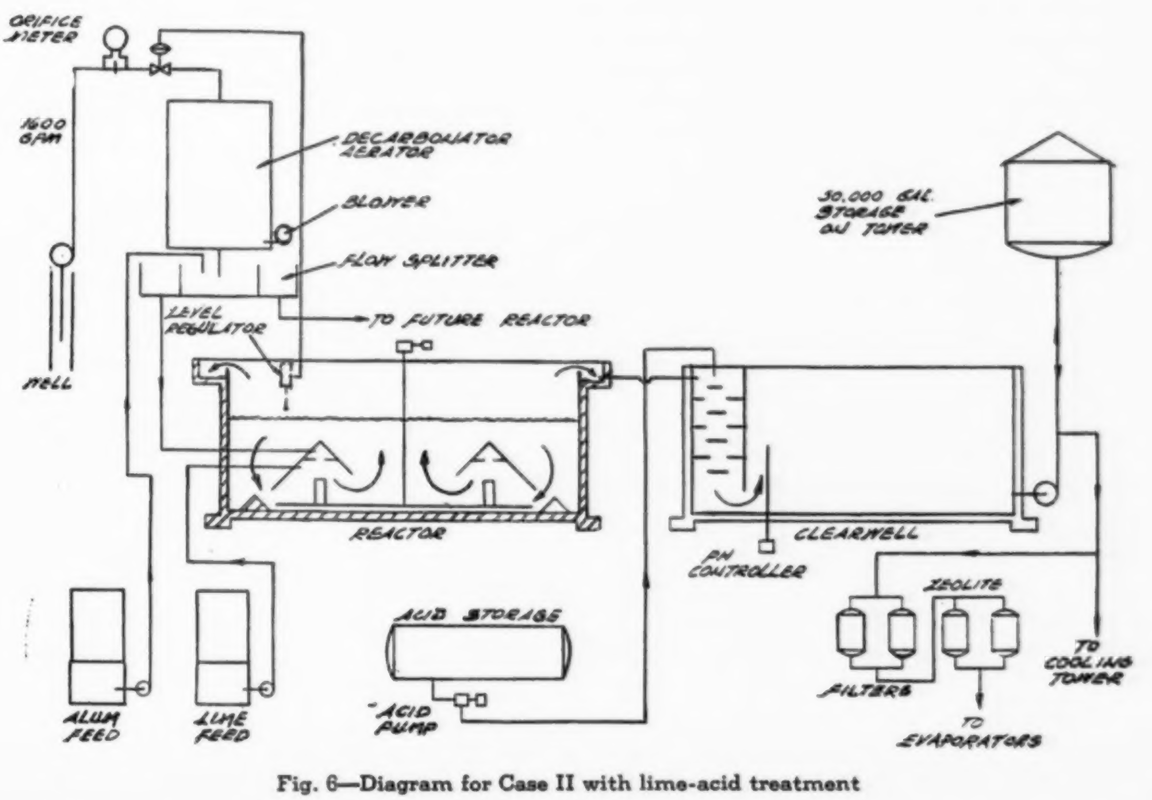


Fig. 6—Diagram for Case II with lime-acid treatment

Sodium Zeolite Treatment

This method is recommended where the hardness and alkalinity of the raw water are moderate in amount and where salt required to regenerate the zeolite is economical in cost. The reaction is:

$$\left.\begin{matrix}Ca\\Mg\end{matrix}\right\}(HCO_3)_2 + Na_2Z = \left.\begin{matrix}Ca\\Mg\end{matrix}\right\}Z + 2NaHCO_3$$

Calcium or magnesium bicarbonate	+	Sodium zeolite	=	Calcium or magnesium zeolite	+	Sodium bicarbonate

The same reaction occurs for the sulfates and chlorides. Thus all the calcium and magnesium salts are converted to corresponding sodium salts which are soluble. The zeolite is regenerated with salt and no chemicals are added to the water.

However, if the alkalinity is high, the sodium bicarbonate present in the softened water will form soda ash in the concentrated recirculating cooling water which may attack the wood of the cooling tower. Also, in some cases the sodium carbonate deposits on neighboring buildings as a white film. An acid feed following the zeolite will reduce the alkalinity to prevent these difficulties.

Sodium zeolite reduces all the hardness to practically zero (1–2 ppm as $CaCO_3$). Thus it will keep the cooling systems very clean. However, if the exchangers have ferrous tubes, corrosion may be experienced and it is then advisable to practice the controlled-scale method. This is accomplished by bypassing some hard water around the zeolite plant and adding acid to reduce the alkalinity. Case III illustrates this arrangement.

Case III—Sodium Zeolite Plant

This is a large oil refinery in the Southwest. Table 5 gives the analyses of the raw and treated water and operating cost. The flow rate treated is 1500 gpm. Three fully automatic sodium zeolite units are used with 5-inch multiport valves, motor-operated. Each unit has a meter which controls the initiation of the regeneration. The regeneration is carried out automatically through the three steps of backwashing, brine introduction and brine rinse. A large concrete wet salt storage basin

CASE III **OPERATING RESULTS SHEET** Table 5

Name Southwestern Oil Refinery Date

Address

Identification:
A) Well water
B) After sodium zeolite an acid and hard water bypass
C) Recirculating cooling water after 5 concentrations.

	Constituent		Analysis in PPM as	A	B	C	D	E
Cations	Calcium	(Ca^{++})	$CaCO_3$	90	15	75		
	Magnesium	(Mg^{++})	$CaCO_3$	33	5	25		
	Sodium	(Na^{+})	$CaCO_3$	161	284	1420		
	Hydrogen = FMA	(H^{+})	$CaCO_3$					
			$CaCO_3$					
Total Cations			$CaCO_3$	304	304	1520		
Anions	Bicarbonate	(HCO_3^-)	$CaCO_3$	196	30	150		
	Carbonate	(CO_3^{--})	$CaCO_3$	0	0	0		
	Hydroxide	(OH^-)	$CaCO_3$	0	0	0		
	Sulfate	(SO_4^{--})	$CaCO_3$	18	184	920		
	Chloride	(Cl^-)	$CaCO_3$	90	90	450		
			$CaCO_3$					
Total Anions			$CaCO_3$	304	304 *	1520		
Total Hardness			$CaCO_3$	123	20	100		
Methyl Orange Alkalinity			$CaCO_3$	196	30	150		
Iron, Total			Fe					
Carbon Dioxide, Free			CO_2					
Silica			SiO_2					
Turbidity								
Total Dissolved Solids								
pH				6.5	5.5	8.3		
pH_S						7.4		
Langelier Index at 120°F.						+0.9		

OPERATING COST

Chemicals	lbs. per 1000 gal	* Chemical cost cents per lb.	Chemical cost—cents per 1000 gallons
Salt NaCl	2.6	0.8	2.1
Acid	1.4	1.5	2.1
			4.2

stores and dissolves the salt to saturated brine of full 23 deg Bé strength. This brine is pumped into the softeners automatically controlled.

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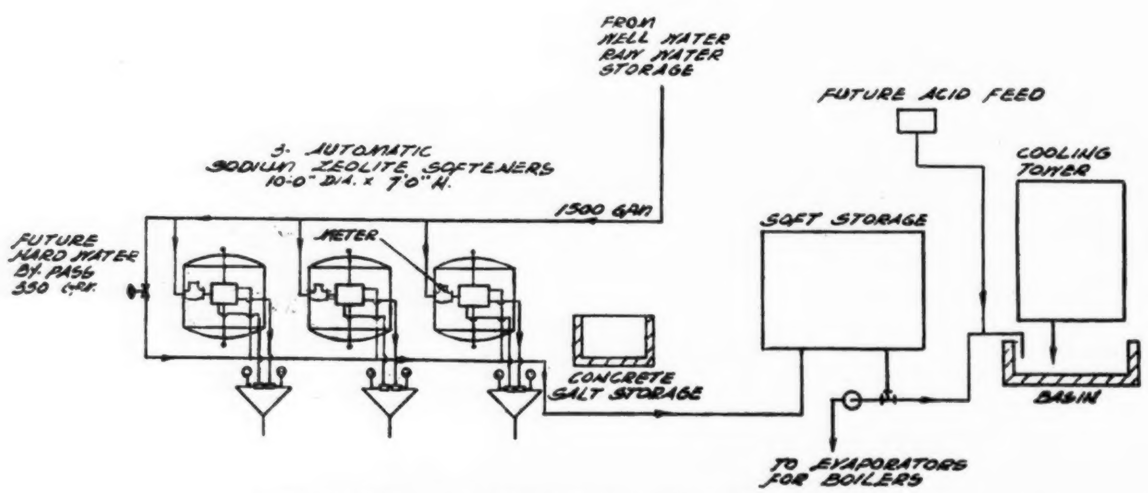


Fig. 7—Diagram for Case III employing sodium zeolite

*Quick Starting of Steam Turbines**

By ROBERT L. REYNOLDS

Mgr., Central Station Turbine Sect., Westinghouse Electric Corp.

Discussed are factors affecting starting time, the effect of boiler arrangement, differential temperature between flange and bolts, bolt heating by steam during the starting cycle, and the advantages of maintaining controlled conditions during starting. A chart is appended showing recommended time for starting after shutdown.

THE time required to start a unit after a shutdown during which the turbine has not been dismantled will depend upon several factors, the most important of which are the following:

(*a*) Length of shutdown.
(*b*) Temperature of the turbine metal prior to starting.
(*c*) Temperature, and provision for control, of steam used for starting.
(*d*) Operation of rotor-turning device during shutdown period.
(*e*) Turbine design, particularly such features as blade clearances and casing flange proportions.

* Presented before Production Committee, Engineering and Operation Section, Southeastern Electric Exchange, Atlanta, Ga., September 29, 1950.

The length of time that the unit has been out of service will determine to a great extent the amount of cooling of the metal of high temperature parts such as throttle valves, steam chests and turbine casings. This rate and amount of cooling will also be influenced by the adequacy of the insulation on the high-temperature parts.

Cooling of the turbine casing will usually not be uniform, with the lower part cooling off at a slightly faster rate than the upper half. Because of this, the casing will tend to "hump," thus reducing the radial clearances between the stationary and rotating parts at the bottom and increasing them at the top. The differential in the rate of cooling can be reduced slightly by rotating the shaft at a higher speed with the turning device. This is particularly important on units operating with steam temperatures of 1000 F and above, making it desirable on such units to roll at about 30 rpm, or even higher, rather than the more common speed of 3 rpm.

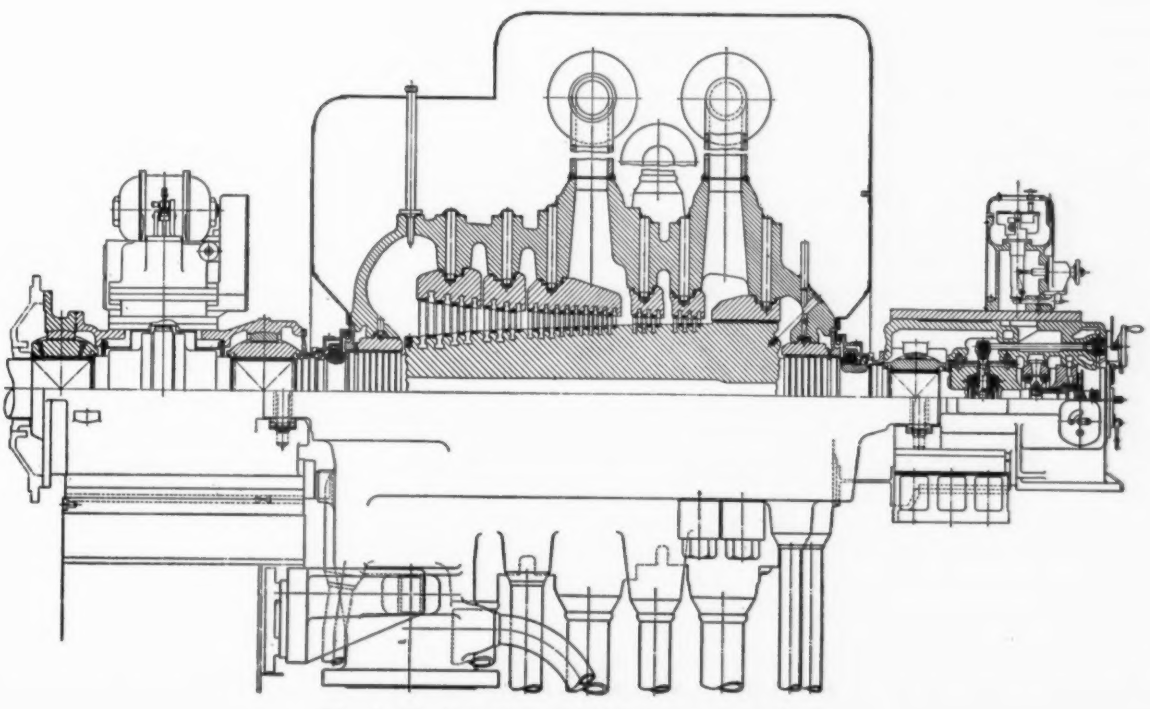
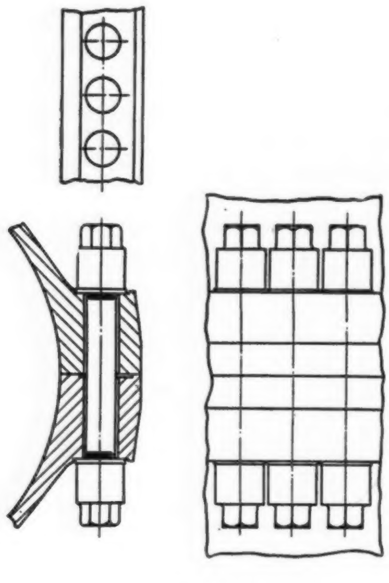


Fig. 1—Section through high-pressure turbine

Measurements taken on several units indicate that the rate of cooling is about 30 deg F for the first hour, decreasing to about 20 deg F per hr after 6 hr and to about 10 deg F in 36 hours. Thus, after an overnight shutdown of about six hours the high-temperature parts will have cooled off about 150 deg F, whereas after a weekend shutdown of some 36 hr the metal will have cooled off about 400 deg F.



HORIZONTAL JOINT BOLTING

Fig. 2—Section through horizontal joint

Effect of Boiler Arrangement and Design

The temperature of steam used for starting will depend upon the design and arrangement of boilers. In a unit arrangement, with a single boiler and turbine, steam temperature will generally be too low unless the turbine has become quite cool after a long shutdown. In a steam header system, where the boilers have been kept in service supplying other turbines in the station, the steam temperature will usually be too high except after a short shutdown.

Thus, the ability of the boilers to supply steam at a temperature about the same as or slightly higher than the metal temperature, which is an important requirement for a quick start, may be quite difficult to attain. This is particularly true on an installation where this factor of quick starting was not considered in the original design.

The type of service for which the boiler has been designed will influence this situation. In one designed for standby service, the steam temperature will reach rated temperature at comparatively small steam flows, whereas steam temperature from a base load boiler will not reach its rated level until the steam flow becomes much higher. Since the boiler designed for standby service generates steam at a higher temperature at low outputs it will generally be more adaptable for quick starts after a short shutdown provided it is suitably equipped with controls for maintaining the steam temperature at the desired level.

Description of Cylinder Joint Design

In order to analyze the effect of quick starting on steam turbines, reference is made to Fig. 2 which illustrates the section through a typical turbine horizontal joint and bolt. This joint is held together by closely spaced through bolts which under normal conditions produce a pressure on the contact surfaces sufficient to keep the joint tight. The contact surface is often divided into an inner and outer surface with the center section at the bolts relieved. Washers under the nuts form a hardened surface for the nut and help to distribute the loading on the spotfaced surface of the flange.

During the heating cycle occurring during starting and increasing load, steam sweeping past the inner well will first heat the inner part of the flange. Heat will then be conducted through the flange at a fairly fast rate. With the through type of bolt as illustrated heat will pass into the bolt at a much slower rate, this heat being transmitted principally by conduction through the washer, thence into the nut and finally into the bolt along the comparatively short thread engagement. Some heat is also transmitted to the bolt by radiation across the clearance space between the flange and bolt, this transmission also being at a comparatively slow-rate.

Thus, as heating takes place the flange will heat at a much faster rate than the bolt. This differential is dependent upon the rate of heating which, in turn, is determined to a great extent by the difference between the metal temperature and the temperature of the steam used for heating.

The differential heating will cause the cylinder flange to expand more than the bolt, especially at the inner surface and increase the compressive stress at the contact surface of the cylinder flange and the tensile stress in the bolts. If this differential becomes excessive, the stresses in the flange and bolt may also become excessive.

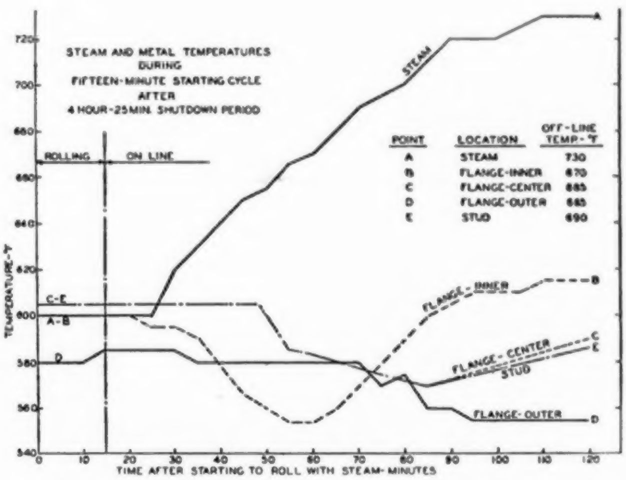


Fig. 3—Flange temperatures during 15-min. start

For example, if the differential temperature between the flange and bolt becomes 150 deg F, which has been measured on some units during the starting cycle, the stresses will increase about 30,000 psi due to a differential expansion of about one mil per inch of length. If then,

the bolts were initially tightened to a tensile stress of about 45,000 psi with a corresponding flange compressive stress of 22,500 psi the stresses will become:

Bolt tensile stress = 45,000 + 30,000 = 75,000 psi
Flange compressive stress = 22,500 + 30,000 = 52,500 psi

With present bolt and cylinder materials these stresses are within the yield point limits of the bolting but this is not the case with the flange. As a result the flange material at the sealing surface will flow plastically, or "crush," whereas the bolts will not be adversely affected.

During the cooling cycle, caused by shutting down or by reducing load, the opposite effect will take place. In other words, the compressive stress on the flange will become less and, if the differential becomes great enough, the joint will leak. In the same manner the bolt tensile stress will reduce and the bolts will tend to become loose, particularly after they have relaxed following exposure to high temperature and stress over an extended period.

This means that potential damage to the flange and bolts occurs during the heating cycle whereas the possibility of joint leakage occurs during the cooling cycle.

We have experienced cases where, with uncontrolled conditions during the starting cycle, the flange temperatures have become much more than 150 deg F higher than the bolts. Under these conditions, it becomes apparent that the joint sealing surface will be damaged and it may even lead to broken bolts. Thus, this condition must be guarded against and any starting cycle, whether fast or slow, must be predicated upon a controlled program in which the following rules are carefully observed:

(*a*) The temperature of the metal when the unit is shut down must take into account, where possible, the

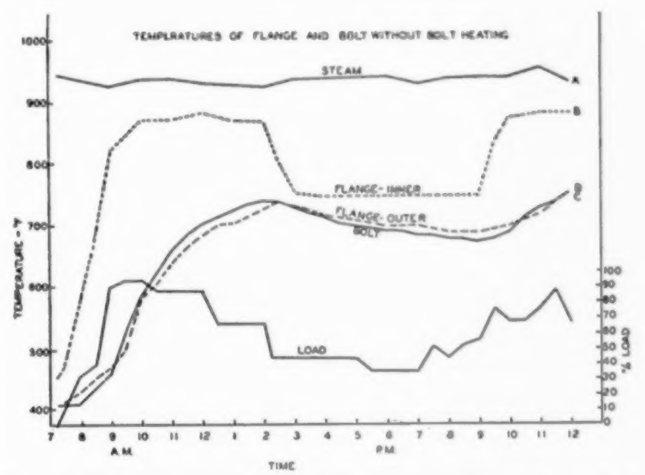


Fig. 4—Temperatures over wide load range without bolt heating

temperature of heating steam which will be available when the unit is returned to service. It is appreciated that this can be done only if the start-up can be definitely scheduled, such as during an overnight or weekend shutdown during which unpredictable repair work is not required on the station equipment. In order to accomplish this, a fairly fast shutdown from heavy loads is dictated if the steam available for starting is at high temperature whereas it is advisable to remove load slowly and to cool the turbine as much as possible prior to being taken out of service if it is planned to start the boiler coincidentally with the turbine and thus use comparatively cool steam for starting.

(*b*) Steam should be admitted to the turbine at or slightly above (say 50 deg F) the temperature of the

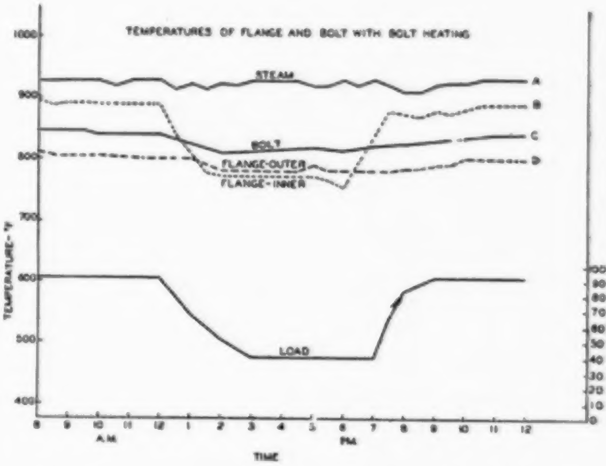


Fig. 5—Conditions with steam heating of bolts

metal in the high-temperature parts of the turbine. Where this cannot be done, the starting cycle should be extended. Means must be provided so that an approximately constant differential between steam and metal temperatures can be maintained as the unit is brought to speed.

Effect of Controlled Start on Flange Conditions

Flange temperatures during a 15-min start under controlled conditions are shown on Fig. 3. It will be noted that steam is admitted at the same temperature as the inner wall at the impulse chamber. It will also be noted that the maximum temperature gradient across the flange does not exceed 60 deg F which means that the stresses in the flange and bolts are kept within safe limits during this starting cycle. The temperature differential between the center of the flange and the bolts is practically nil, which is due to the fact that the flange bolts are of the stud type which results in a much better heat transmission from the flange to the bolt along the thread engagement.

Effect of Bolt Heating During Starting Cycle

One method for reducing temperature differentials between flange and bolts is to circulate high-temperature steam through the space around the bolts. The effect of such heating is illustrated by a comparison of the curves in Figs. 4 and 5.

In Fig. 4, the flange and bolt temperatures are shown throughout a wide range in load with no steam circulated around the bolts. It will be noted that at times the temperature gradient across the flange and the differential temperature between the flange and bolts becomes excessively high. At the worst point this temperature gradient becomes 360 deg F which results in extremely high stresses in the flange and bolts.

Fig. 5 shows the same conditions when high-temperature steam is circulated around the bolts. It will be seen that the temperature gradient is considerably less, being only 100 deg F under the most extreme condition. Comparison of the flange and bolt temperatures is even closer. It is obvious that this steam circulation has a very beneficial affect and will permit not only a much

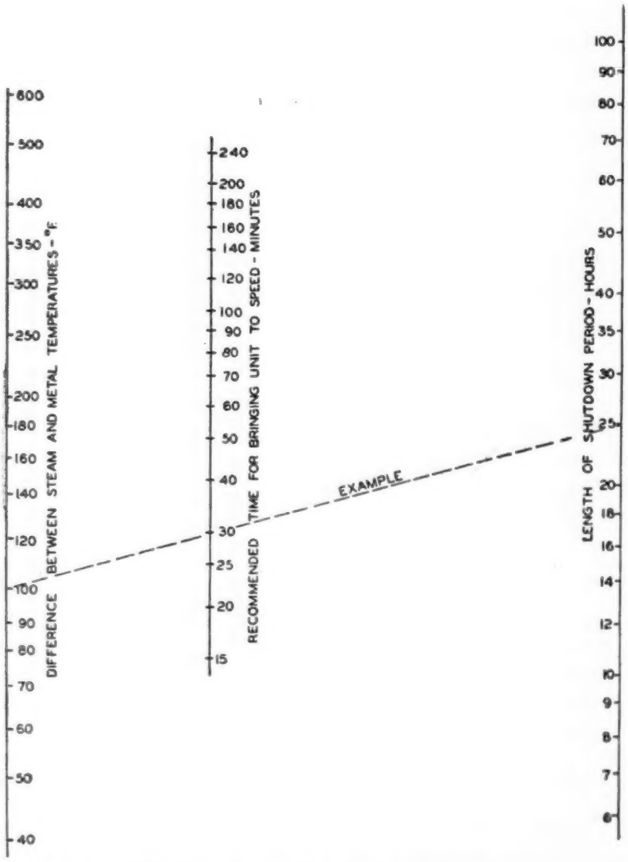


Fig.6—Recommended time for bringing unit to speed following shutdown period without dismantling

faster start but also will permit load to be imposed at a much faster rate.

In order to decide whether to shut down a unit or to run it at reduced load it is necessary to make a detailed analysis of each system. Factors affecting this decision are:

(*a*) Comparative values of off-peak load to installed capacity.
(*b*) Shape of efficiency curve of boiler, turbine and other equipment.
(*c*) Ability of turbine to be started and loaded quickly without damage.
(*d*) Need for short-time repairs or adjustments.

Efficiency of boilers and turbines are almost always poorer at light than at heavy loads. This is particularly true if the off-peak loads are less than half rated load. As a rough rule, it would prove economical in most cases to keep the unit in operation provided it carries half load or above. If, however, it becomes necessary to transfer load from a more efficient unit to a less efficient unit during the light load periods it might swing the balance in the other direction and justify shutting down the less efficient unit.

Some turbines, particularly those of modern design, are better suited to quick starting and to rapid changes in load even though they may be operating with much higher steam pressures and temperatures. However, these units, being of modern design and operating under higher steam conditions, would be the ones which should be kept in service during the light load periods. This places the burden of shutting down and starting up chiefly on the older units, which were not primarily designed for this type of operation, except on those systems where the night or week-end load is only a small fraction of the peak load.

The need for making minor repairs or adjustments during the shutdown periods may dictate the desirability for taking a unit out of service. This is a factor which can usually not be predicted nor scheduled.

Since the loss in output and fuel during the starting cycle can become quite large, it is extremely important that the starting time be reduced as much as practicable consistent with proper treatment of the apparatus.

From an analysis of readings taken during "quick starts," this type of operation, when conducted under controlled conditions, is fundamentally sound and subjects the turbine to less severe treatment than when following the somewhat arbitrary rules of slow starts as established in the past.

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Eleventh Annual Water Conference

The relative merits of evaporators versus demineralizing and silica removal, sampling of steam for purity determination, comparison of methods of carbon dioxide control in condensate, studies of boiler scales at 2400 psi, and hot lime-sodium-zeolite treatment were among the topics discussed. Abstracts of the principal papers of interest in the steam power field are included along with some of the informal discussion.

THE Eleventh Annual Water Conference, sponsored by the Engineers' Society of Western Pennsylvania, was held at the Hotel William Penn, Pittsburgh, on October 16–18 with about 350 engineers and chemists in attendance. As had been the case at preceding Conferences, there was enthusiastic participation in the discussion periods following each of the formal papers.[1]

Protection Against Pitting

H. Lewis Kahler and **Charles George** of W. H. & L. D. Betz, Philadelphia, presented a paper entitled "The Dianodic Method for the Prevention of Pitting and Tuberculation." This method is said to aid in preventing water-side corrosion and requires relatively low concentrations to achieve the same benefits as are obtainable at much higher concentrations using such single treatments as chromate, phosphate and silicate. The term "Dianodic" is used to identify a specific combination of two anodic inhibitors (phosphate and chromate) in proper ratio at a controlled pH, as distinguished from the conventional use of chromate and phosphate for preventing corrosion and scale. Experimental evidence indicates that the specific combination under discussion acts as a single agency, and pit reductions of from 80 to 90 per cent may be expected.

Anodic inhibitors are efficient corrosion inhibitors only if used in sufficient quantity. Both phosphate and chromate are anodic inhibitors, and it was contrary to established principles to find that a combination of these anodic inhibitors at low concentrations and with controlled pH would reduce pitting to a minor fraction of that which would be obtained with either material separately. While it might be expected that with fewer pits there would be greater depth, such was not the observed case; actually the pits were very shallow and seemingly non-aggressive. Observations of test specimens at 150 magnifications show no measurable depth for the affected areas, while pit depths of 0.1 and 1.0 in. per year penetration were secured with chromate and phosphate treatments, respectively, under the same conditions.

As concerns pH limitations, the Dianodic method proved most effective with values ranging from 5.0 to 8.5. From the standpoint of general corrosion the use of this method to reduce pitting and tuberculation is claimed to involve no disadvantages. Tests have shown that it is as effective against corrosion or steel loss as sodium chromate treatment alone and far superior to polyphosphate alone. Tuberculation is more severe with chromate treatment due to the formation of iron oxide over isolated pits than it is with phosphate treatment with its dispersing action. However, results in the prevention of tuberculation with the Dianodic method are said to be superior even to phosphate treatment.

Operating results in cooling systems, using waters of widely varying characteristics, have confirmed the laboratory and pilot plant data on the ability of this method to minimize pitting and tuberculation. Freedom from general corrosion and marked reduction in pitting and tuberculation have been obtained with circulating waters of 3000 to 5000 ppm chloride content.

Discussion

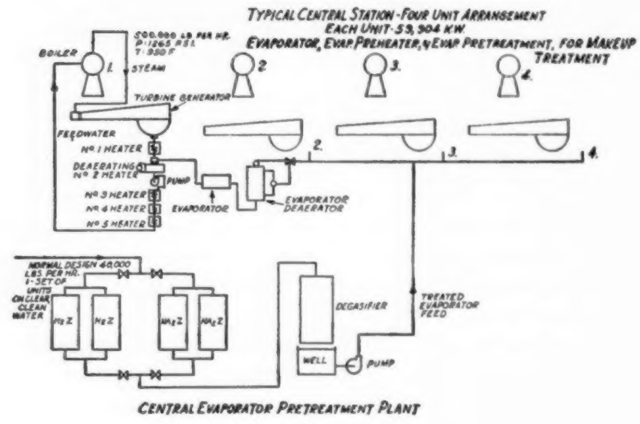
The required close control of pH might be difficult under some operating conditions, it was pointed out. The most promising application appears to be in cooling tower service, although there are many plants having towers but not the necessary laboratory facilities to check corrosion problems. With the increasing use of closed systems as a result of water shortages, chemical treatment of cooling water is becoming more attractive.

In response to a question concerning the length of the reported tests, it was stated that the original results were substantiated by actual plant operation over a period of one to two years with water temperatures up to 160 F. To prevent pitting in refrigerating systems employing brines, it was reported that 150 ppm using the Dianodic method would perform as satisfactorily as 1630 ppm chromate under similar conditions.

Evaporation vs. Demineralizing and Silica Removal

"High Pressure Boiler Feedwater Treatment, Evaporation vs. Demineralizing and Silica Removal" was the title of an economic study made by **V. J. Calise,** technical director of Graver Water Conditioning Co. For many years the makeup to high-pressure central stations has been distilled water obtained by evaporation, but with the practical development of demineralizing and silica removal by ion-exchange, another method has been made available for producing water of

[1] Copies of the complete papers and discussions may be obtained for $7.50 by writing to the Society office at the same hotel.



CENTRAL EVAPORATOR PRETREATMENT PLANT

distilled purity. A number of utility power plants are now operating or have under design demineralizing and silica removal ion-exchange equipment to produce boiler feedwater makeup. While most of these are operating with makeup percentages ranging from 0.75 to 1.5 per cent, some are employing such removal equipment where more than 20 per cent of treated makeup is required.

As a basis of comparison of evaporators with pretreatment and demineralization plus ion-exchange silica removal, a central station was assumed to consist of four 60,000-kw single boiler-turbine-generator units. Each boiler would have a steam capacity of 500,000 lb per hr at 1250 psig and 950 F. For both the evaporators and demineralizers the normal percentage makeup was assumed to be one per cent or 5000 lb per hr per unit, but for design purposes the individual units were provided with a capacity of 10,000 lb per hr. A central two-step demineralizing and silica removal plant, as well as an evaporator zeolite pretreatment plant was calculated for both cases. It was assumed that the effluent from the demineralizing equipment and the evaporator would contain less than 1.5 ppm total dissolved solids.

Based on ultimately treating 40,000 lb per hr of clear clean water such as is found in Lake Michigan in the Chicago area, the installed investment for zeolite pretreatment plus evaporators and evaporator deaerating heaters amounts to $67,500, of which $14,500 is the installed zeolite cost and $53,000 is the evaporator equipment cost. The operating cost with evaporators and water pretreatment consists of (1) loss in power due to degradation or loss of available energy in steam required for evaporation; (2) loss of heat energy in evaporator blowoff; (3) cost of chemical pretreatment of evaporator makeup; (4) cost of replacement of zeolite; (5) labor maintenance cost; and (6) amortization on installed equipment.

In evaluating losses due to degradation of energy it was calculated that at full load on a 60,000-kw turbine the net power available would be diminished by 96 kw. With four units operating at 80 per cent load factor and assuming the selling price of power at 1 cent per kwhr, the charge for evaporator operating would be $74 per day. This value might be reduced between 25 and 35 per cent, or to $52 per day, by the use of evaporator condensers. Eliminating labor operating cost for both evaporators with pretreatment and demineralizers plus silica removal, which are assumed to be equal, the daily cost of evaporator operation for Chicago water would amount to $73.94 per day, which includes all six factors previously mentioned.

For demineralizing and silica removal, central treatment is proposed on the basis of a two-bed demineralizing and silica removal plant having two cation and two anion units taking a load of 40,000 lb per hr at a rate of 4 gpm per sq ft. The installed demineralizer cost under these conditions was estimated at $46,000 for Chicago water. The cost of operating this equipment would consist of (1) chemical cost, (2) zeolite replacement cost, (3) labor maintenance cost and (4) amortization on installed equipment. For Chicago water the operating cost with demineralizing and ion-exchange silica removal amounts to $17.85 per day exclusive of operating labor.

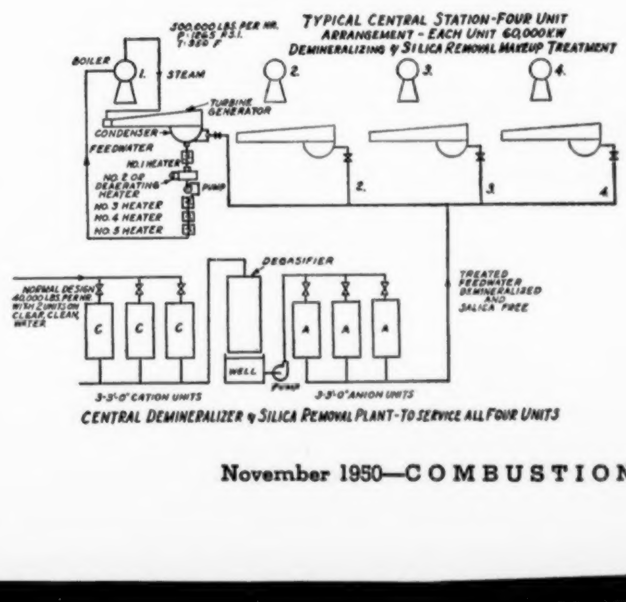
Comparisons of the two methods were also made for treating New York City water and Pittsburgh water. In all three cases the savings estimated for using ion-exchange equipment amounted to approximately $50 per day. The major item in such comparisons is the loss of available energy due to steam pressure drop across evaporators. Both methods can provide effluent containing dissolved solids of less than 1.5 ppm. In addition to the economic factors, the demineralizing equipment offers the advantage of flexible operation independent of turbine load.

Discussion

J. H. Harlow, of Philadelphia Electric Co., told of the construction of a demineralizing plant having a capacity of 600,000 lb of water per hr at the Schuylkill Station, where a part of the steam is used for heating without condensate return. The new installation is located in a separate building and consists of a two-bed system with a degasifier. Philadelphia city water is used, and it is expected that effluent quality will be high and that regeneration will take place at reasonable intervals.

D. Forty of the Public Service Co. of Northern Illinois reported that demineralizers were being installed in new stations operating at 1800 psig and that studies and operating experience have shown that demineralizer plants are less expensive and more satisfactory than evaporators on Lake Michigan water.

The amount of heat degradation and the costs chargeable to it for evaporator operation were questioned. It was also pointed out that the cost of treatment with demineralization varies with the amount of dissolved



CENTRAL DEMINERALIZER & SILICA REMOVAL PLANT-TO SERVICE ALL FOUR UNITS

solids, whereas the variation in cost using an evaporator may be less. Considering the cost of space in a modern central station, one advantage of the demineralizer is that it may be located in a separate building where it remains independent of the steam cycle. The relative ease of operation of the two methods was open to question, and it was stated that demineralizing cannot be applied to sea water or strong salines. Compression distillation was mentioned as one means of reducing the degradation of energy loss attributable to the evaporator, and it may prove interesting for future analysis.

Vapor Purity in Evaporators

R. M. Buchanan and **A. A. Pace** of the Duquesne Light Co. presented a paper entitled "Evaporator Purity as Related to Station Design." Taking everything into consideration it would appear that the vapor from an evaporator should be of a purity at least equal to that from a boiler and that it should not be unreasonable to produce a vapor with 0.5 ppm or less dissolved solids. However, a survey made by the Prime Movers Committee of the Pennsylvania Electric Association in 1949 showed that only seven of 22 evaporators reported were capable of producing a vapor purity of 1.0 ppm at rated capacity and that nearly half of the evaporators had to be dropped to 50 per cent of rating or below to produce a reasonably good steam.

Because of the importance of the evaporator, its design and operating characteristics deserve special attention. Carryover that does not exceed 1.0 ppm dissolved solids can be attained by considering the following points:

1. Purchasing an evaporator of adequate size.
2. Arranging station design so that evaporator operation is not affected by turbine load changes.
3. Providing evaporator feedwater of such quality that operation may be continuous without corrosion and scale troubles.
4. Operating at predetermined optimum load, water level and liquor concentration.

Selection of the evaporator vapor pressure should be made at a level where feedwater can enter and blowdown water can leave the shell without pumps. Cost of shell design can be held to a minimum if the vapor pressure is below 52 psig. In the survey previously mentioned it was disclosed that 24 out of 38 evaporators reported are arranged so that vapor pressure varies with load changes. Of these, eleven experienced carryover during load changes.

In sizing evaporators it is the recommendation of the authors that the known makeup value be multiplied by four to set evaporator capacity. They also urge that the diameter and length of shell should be specified for a given capacity.

The two control devices required for an evaporator are an air-operated level controller for the feedwater and a constant-vapor-pressure controller. Necessary instruments include a pressure gage, vapor pressure gage, vapor steam flow meter, a blowdown flow indicator, a two-point vapor conductivity recorder, a blowdown conductivity recorder, and industrial thermometers on the deaerator and blowdown heat-exchanger.

Degasification is recommended because it prevents oxygen corrosion of evaporator parts and decreases the amount of gaseous impurities, such as carbon dioxide and ammonia, entering the system.

Discussion

The matter of silica carryover from evaporators operating at 5 psig was the subject of some speculation. It would seem improbable that this carryover results from vaporization and likely that it may be caused by entrainment in liquid particles. By reducing the disengaging velocity of the evaporator to less than 0.25 fps, moisture may be eliminated, and it was thought that more attention in evaporator design should be given to the amount of disengaging area, which may be even more important than heat-transfer surface.

It was pointed out that vapor quality from evaporators is dependent upon area of evaporation, flow rate, and vapor density, the last being dependent upon the vapor pressure in the shell. There was considerable discussion of the effect of variation in station load and its effect upon evaporator output.

Steam Sampling

"Sampling of Steam for the Determination of Purity" was the title of a paper by **B. J. Cross** of Combustion Engineering-Superheater, Inc. In a generally accepted sense, steam purity refers to solid impurities or to those substances that remain as solids in the residue after a sample is evaporated to dryness. Purity of steam is expressed as parts per million of impurity, the usual specification being one part per million or less of impurity. The steam quality refers only to the moisture content, and while steam purity may be estimated from steam quality if the solids content of the contained moisture is known, this is not always a safe assumption. Examples of this occur when steam washers are used and under foamy water conditions.

Because of the more strict present-day requirements for steam purity, it is suggested that sampling procedures which may have been adequate in the past be reviewed in order to improve them and bring them close to the reality of present-day practice. Practical requirements necessitate that a sample be limited in size but still be representative of a large mass of material. It must contain all ingredients, both the impurities and the values, in the same weight proportion found in the mass sampled. Some factors contributing to sampling difficulty are large particle size, great variation in particle density, and uneven distribution of particles through the mass to be sampled.

At the usual steam sampling rate of 100 lb per hr the impurity in the matter withdrawn is less than 0.7 grain per hour. Since steam lines contain bends, elbows and valves which disturb the flow and tend to segregate impurities, the sampling procedure must be based on assumptions, of which the following are most important:

1. The velocity front is reasonably flat. Since the usual flow rate in steam lines is well within the range of turbulent flow, and since it is possible that supersonic

vibration may exist to knit together the elements of flow, this assumption appears reasonable.

2. The density difference of the steam and the mist, fog and particulate matter carried with it is of the same magnitude as that for steam and water at the pressure and temperature of the steam in the line.

3. The distribution or dispersion of the impurities over the sampling section, if not uniform, is at least symmetrical along the axis of the sampling nozzle in the pipe.

The presence of a film of moisture carried along the wall of the pipe poses a difficult problem in attempting to locate a sampling port which would include such a film in its proper proportion in the sample. A design of sampling nozzle was proposed by means of which a representative sample could be collected under the assumed conditions.

There are two basic principles in sampling steam. First, the velocity entering the ports of the sampling nozzle must be the same as the line velocity of the steam. Second, each port of the sampling nozzle should represent an equal area of the sampling section. These principles are the same as those on which is based the recently adopted tentative method for steam sampling, ASTM D-1066.

Discussion

Prof. **W. C. Andrae** of Cornell University stated that the fine points of detail necessary for obtaining a representative sample are too little understood and too often dismissed in favor of a rule-of-thumb solution. Use of the modified nozzle to bring the liquid film on the wall of the pipe out to where it can be properly handled appears to be a good idea.

Prof. **H. M. Cather** of West Virginia University agreed generally with the principles set forth but expressed some doubt about the necessity of adjusting the sampler inlet port velocity to steam line velocity. He pointed out that under highly turbulent flow conditions the trajectory of the particles of impurity is erratic and not necessarily parallel to the pipe axis.

According to **E. P. Partridge** of Hall Laboratories, Inc., a distinction must be made between the commercial viewpoint of steam sampling and that of the engineer searching for a practical means of reducing carryover and improving steam purity. The emphasis in the former is in securing a truly representative average sample, whereas in the latter the purpose is to collect a sample as rich as possible in contaminants at a point as close as possible to the source of contamination. Because of the extreme turbulence in a steam line he suggested that the precautions outlined by the author might not be necessary. He urged actual testing to demonstrate the comparative results with different sampling devices and felt that such a project might be sponsored by the Joint Research Committee on Boiler Feedwater Studies.

R. A. Lorenzini of Foster-Wheeler Corp. felt that from the point of view of velocity distribution it appeared desirable to install a sampling nozzle near the entrance to superheater tubes. Since the local velocities and velocity distribution in the steam space of the drum are not readily ascertainable, that location is not considered satisfactory for steam purity measurements. He pointed out the practical difficulties of finding a physical location in a power plant which conforms with the ideal condition of having a sampling nozzle not less than 45 diameters downstream from the last disturbance with 15 diameters of straight pipe following the nozzle. He also proposed that the particle size and distribution could be developed by mathematical analysis.

Control of Carbon Dioxide in Condensate

T. B. Kneen and **R. R. Kountz** of Pennsylvania State College delivered a paper entitled "An Economic Analysis of Condensate Corrosion Control Methods." The mechanics of corrosion of condensate return lines is understood as the attack of ferrous and cuprous alloys by carbonic acid. This corrosion may be controlled by substituting acid-resistant alloys for the usual metals, by preventing the formation of carbon dioxide in the steam, or by neutralizing the effect of carbonic acid in the condensing equipment.

The study was made in an attempt to establish a rough yardstick by which the overall cost of various corrective measures could be evaluated in a typical small steam generating plant. Although the effectiveness of correction varies with the several methods, it was assumed that in all cases the replacement of condensate return lines was reduced in a similar degree. The pilot plant is assumed to have an annual steam load of 145 million pounds at 125 psig with a short winter peak of 50,000 lb per hr. There are three 30,000 lb-per-hr steam generating units, of which two normally operate during the winter months; makeup is assumed to be 25 per cent; and the plant is expected to service more than a mile of buried steam and return lines as well as smaller piping located in between 20 and 30 buildings.

On a differential basis between treatment methods, where no treatment is employed to reduce the alkalinity of the waters, ammonia or a filming amine compound holds the economic advantage. Where partial decarbonation treatment is employed, the use of relatively small quantities of neutralizing amines is economically advisable. When complete decarbonation of the makeup water is employed, the system involving hydrogen zeolite with degasification and caustic feed offers the lowest annual cost.

Where a water of low hardness and low mineral content is used for makeup, a filming amine compound is favored due to the ease of application and lack of feed control measures. With a highly mineralized hardwater, the use of a hot lime softener followed by zeolite softening and subsequent treatment of the steam with a neutralizing amine seems most practical.

Boiler Scale at 2500 Psi

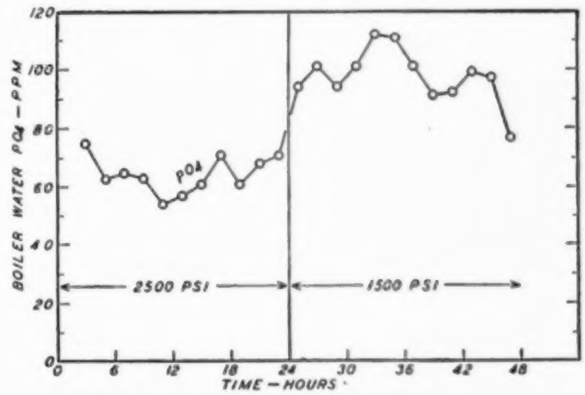
"Experimental Studies of Boiler Scale at 2500 Psi" was the title of a report by **J. A. Holmes** and **C. Jacklin** of National Aluminate Corp. Representing a continuation of experimental studies reported at previous Water Conferences, the paper is based upon tests conducted upon a laboratory boiler heated by electronic induction. Heat-transfer rates range from 100,000 Btu per sq ft per hr at an evaporation rate of 15 lb per hr to a maximum of 225,000 Btu per sq ft per hr, the latter

being sufficient to cause metal failures similar to those experienced in regular plant boilers.

Under test conditions boiler pressure was held to within 100 psi, plus or minus, of the indicated value, and heat rates were maintained within an average of plus or minus ten per cent. All feedwater was mechanically deaerated and treated with sodium sulfite to maintain a sulfite residual of 10 to 20 ppm in the boiler water. Sodium salts were used and a concentration ratio of 30 was maintained in the boiler water.

Tests indicated that the behavior of calcium and magnesium compounds in the feedwater were similar to those previously reported at 1500 psi and lower heat-transfer rates. Deposits may lay down on all heated areas of the boiler regardless of rate of heat transfer, and deposition rate is mainly dependent upon the amount of calcium and magnesium in the feedwater.

Magnetic iron oxide occurs over all ranges of pressure and rates of heat transfer, but usually above 250 psi, being especially troublesome where heat-transfer rates are high. Rate of deposition is chiefly a function of iron concentration in feed and boiler water, while the rate of heat transfer determines the extent of caustic corrosion resulting from caustic harbored in magnetic iron oxide.



Boiler water phosphate curve showing evidence of phosphate hide-out with reduction of pressure from 2500 psi to 1500 psi

Sodium ferrous phosphate occurs under conditions of high pressure and high heat transfer with phosphate present above a certain limit. Deposits occurred only on areas of excessive rates of heat transfer which were also partly steam blanketed.

In order to verify whether a deposit of sodium ferrous phosphate is responsible for sodium hideout, as has been reported, a two-part test was made. The first half was run at 2500 psi for 24 hr with a heat-transfer rate of 165,000 Btu per sq ft per hr and an average phosphate concentration of 64 ppm. With conditions unchanged except for reduction in pressure to 1500 psi, the test was continued for another 24 hr. during which time the average phosphate concentration increased to 98 ppm, as shown in the accompanying curve. These higher phosphate readings indicate that sodium ferrous phosphate formed at higher pressure may go into re-solution at lower pressure. This would explain the increase in phosphate concentration which has been observed when there has been a reduction in boiler pressure or rating.

Acmite or sodium iron silicate occurs under conditions of high pressure, high rates of heat transfer and presence of silica. Deposits are more uniformly distributed in areas of high heat transfer and do not appear to require steam blanketing, as is the case with sodium ferrous phosphate.

Analcite occurs under conditions of high pressure, high rates of heat transfer and presence of certain concentrations of alumina and silica.

Discussion

Experimental boilers, it was stated, have reproduced conditions found in actual steam generating practice and have verified much of the theory of water treatment. One limitation is that it is difficult to obtain accurate measurement of metal temperatures in the small experimental units. Considerable significance was attached to the fact that silica-compound deposits were found in regions of maximum heat transfer having some steam blanketing.

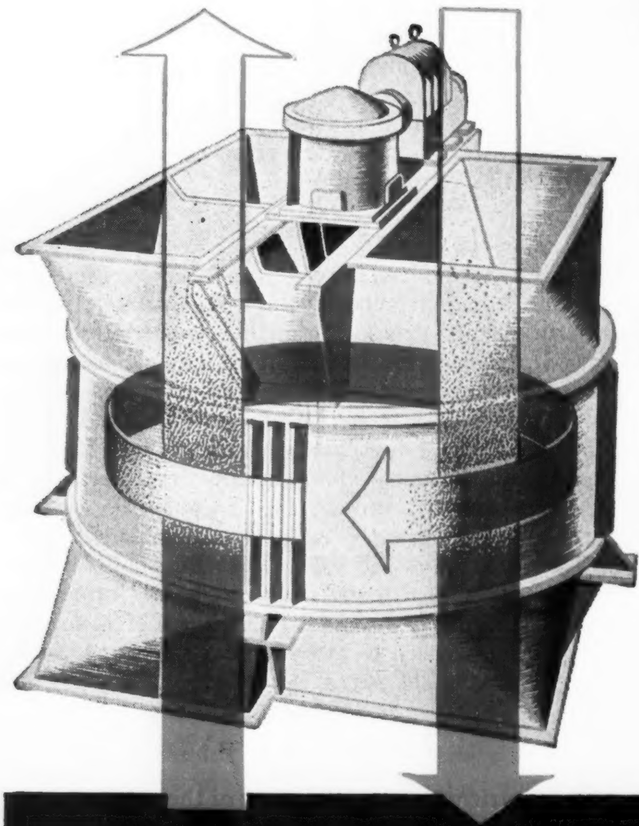
One discusser suggested that a small boiler of similar design be used to study experimentally possible alloy materials suitable for corrosion-resistant tubes. It was reported that the electronic method of induction heating could be used to provide heat transfer rates as high as 1,300,000 Btu per sq ft per hr.

Other Papers

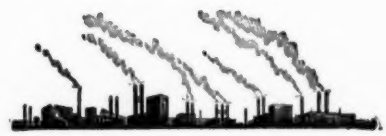
W. S. Morrison and **A. H. Kahler** of the Illinois Water Treatment Company presented an "Initial Report of Operating Data from Industrial Mixed Bed De-Ionizing Units." The single-column method of de-ionizing has proved to be an effective method and has produced water at room temperature having a conductance of 89 per cent that of theoretically pure water and with a silica content of less than 0.1 ppm.

"Hot Lime Treatment Followed by Sodium Zeolite" was the title of a paper by **S. B. Appelbaum** of the Cochrane Corp. While this treatment is relatively new in the United States, it had been in use in Germany before World War II. Its major field of application appears to be in high-pressure boilers having high makeup, where silica must be at a minimum. The treatment is capable of producing low alkalinity, zero hardness, and marked reduction in solids at very low cost.

J. R. Denton of Worthington Pump and Machinery Corp. and **R. I. Smith** of Public Service Electric and Gas Co. discussed "Evaporator Feedwater Treatment at Sewaren Generating Station." In this station the evaporator is located on a platform adjacent to the turbine, and a steam jet deaerator is placed ahead of each evaporator. Because of the high silica content of water available at Sewaren a cation-exchange system operating on the hydrogen cycle was adopted for pretreatment of the makeup water in advance of the evaporator. This water treatment operates automatically except for regeneration, the frequency of which is based on the conductivity of the effluent. The authors reported that silica content of the makeup over a five-month period was held to 0.85 ppm and that the evaporator has performed satisfactorily. High quality vapor has been produced at the same time that evaporator maintenance has been minimized, while automatic operation of the pretreatment plant has proved successful.



this preheater can save you money whatever your fuel



the Ljungstrom AIR PREHEATER

The Ljungstrom operates on the continuous regenerative counterflow principle. The heat transfer surfaces in the rotor act as heat accumulators. As the rotor revolves the heat is transferred from the waste gases to the incoming cold air.

All fuels burn better with preheated combustion air, and it is a "must" for many of them, such as high moisture powdered coal. In addition, the *continuous regenerative counterflow* principle of Ljungstrom permits reliable operation at low exit gas temperature. This assures the greatest possible heat recovery . . . reduces the amount of fuel required.

The efficiency and reliability of the Ljungstrom air preheater is a matter of record in industrial and utility plants throughout the country. That is why every year a constantly increasing percentage of the installed boiler capacity is equipped with Ljungstrom air preheaters.

If you are planning a new installation, or modernizing your present one, our engineers will welcome the opportunity to show you how the Ljungstrom can raise the efficiency of your plant.

THE AIR PREHEATER
60 East 42nd Street, New York 17, N. Y.
CORPORATION

Facts and Figures

A large boiler is lower in first cost than two boilers of half the capacity.

●

Heat transfer rates through economizer surface range from 3000 to 4500 Btu per sq ft per hr.

●

Use of small-diameter, thin-walled tubes in forced-circulation boilers permits higher heat-absorption rates.

●

The United States accounts for approximately 35 per cent of the world's coal output, Continental Europe (including Germany) produces about 41 per cent, and Great Britain $12^1/_2$ per cent.

●

The principal function of chromium in alloy steel for use at elevated temperatures is to improve the scaling resistance by formation of a protective oxide. Inclusion of molybdenum increases the strength.

●

According to the Federal Power Commission, the nation's electric power generating plants burned 55 per cent more natural gas in 1949 than they did in 1948.

●

The thermal efficiency of steam turbines increases with higher pressures, whereas the thermodynamic efficiency decreases; but the latter increases with size of the unit.

●

Mechanical cooling towers can have smaller areas than atmospheric towers because of greater intimacy of contact between air and water, which permits more water to be distributed per square foot.

●

According to a statement by A. R. Hellwarth of Detroit at the Annual Meeting of the Engineers' Council for Professional Development, industry invests at least $10,000 and two years of time before a newly recruited engineer is able to accept full responsibility of a job in a modern industrial organization.

●

Partly through ECA assistance, the power capacity of Italy is being augmented by the construction of numerous steam stations, with the result that the total installed generating capacity is changing from 98 per cent hydro and 2 per cent steam to 75 per cent hydro and 25 per cent steam.

●

The American Petroleum Institute is authority for the statement that of all oil wells drilled in the United States since 1859, some 23 per cent have been dry, and only one well in five has turned out to be a producer. A total of more than 39,000 wells were drilled in 1949, including a large number of "service wells" which are those drilled for the injection of water or gas to increase the flow of oil.

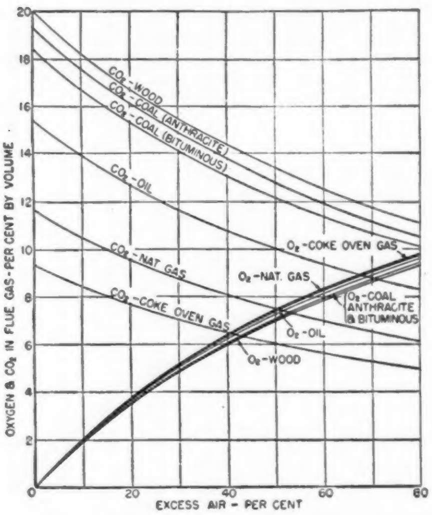
●

Congress has lately given statutory sanction to the revised electrical units as determined by research at the National Bureau of Standards. However, the magnitude of the changes is small, in no case differing more than one-twentieth of one per cent from the previously accepted units.

Annual Joint Fuels Conference

An attendance of more than three hundred marked the Thirteenth Annual Joint Fuels Conference, sponsored by the Fuels Division of ASME and the Coal Division of AIME, which was held at the Hotel Statler, Cleveland, Oct. 24-25.

The first paper at the opening session was on gas analyzers and was given by **C. H. Barnard** of Bailey Meter Co., who discussed the application of automatic gas analyzers and control from gas analysis on various combustion processes.



Relation between oxygen, CO_2 and excess air in an oxidizing atmosphere

For oxidizing atmospheres, a catalytic combustion-type oxygen analyzer is employed, using a standard fuel to burn out the excess oxygen on a catalyst filament; whereas for reducing atmospheres a similar analyzer uses air for fuel to burn unburned combustible gas.

A complete, high-speed sampling system was described which will handle dirty, high-temperature gases, cleaning and delivering them to the analyzer in a brief time.

Stoker Types Discussed

A panel discussion dealing with the relation between coal characteristics and coal-burning equipment included remarks on "Underfeed Stokers," by **J. S. Bennett** of American Engineering Co.; "Pulverized Coal," by **Roger Curfman** of Cleveland Electric Illuminating Co.; "Spreader Stokers," by **Earl Beckwith** of The Detroit Stoker Co.; "Chain Grate Stokers," by **Harry Huston** of Johnson & Jennings; and "Cyclone Furnaces," by **Frank Gilg** of Babcock & Wilcox Co.

With regard to underfeed stokers, **Mr. Bennett** observed that while some coals may be difficult to burn at high rates without cinder discharge, in general, no cinder recovery is necessary with this type of stoker and there is little or no smoke. If the coal is friable, larger size is permissible than with non-friable coal, and ash-fusion temperature is an important factor. He mentioned that water cooling permitted the burning of lower grade coals and cited one underfeed installation serving units of around 500,000 lb per hr.

Discussion by a representative of another manufacturer of multiple-retort underfeed stokers revealed that it had sold twelve so far this year, aggregating some 800,000 lb per hr of steam generating capacity.

Mr. Curfman reviewed troubles incident to high sulfur in attacking bunkers, the effect of excessive moisture on coal feed and the desirability of high grindability.

Spreader stokers, said **Mr. Beckwith,** can handle a wide range of coals, with the exception of anthracite; coke breeze and semi-anthracite require a water-cooled furnace and the proper percentage of fines. Although coal of $1^1/_2$ in. down may be burned, preference is given to $^3/_4$ in.–0. Ash content may be disregarded with the continuous-discharge type, although provision should be made for cinder recovery. The present top size for steam generating units now in service, so fired, is 340,000 lb per hr. Heat release rates per square foot of grate, as cited by Mr. Beckwith, range between 350,000 and 450,000 Btu for the hand-cleaned type and 600,000 to 750,000 Btu for the continuous-discharge type. However, designs involving a heat release of 900,000 Btu per sq ft per hr are now under way.

Mr. Huston mentioned the difference between the chain-grate and so-called traveling grate types. Ash content, he observed, is of minor importance; although 7 to 8 per cent may be considered a minimum and above 14 to 15 per cent may involve carbon loss at high rates of burning. With improvement in control, caking coals are now being burned on chain-grate stokers and where high air preheat is employed, use of alloys becomes necessary for certain stoker parts. Size consist is important, with a top size of $1^1/_4$ in. preferred. However, with some coals up to 40 per cent fines is permissible if provision is made to avoid segregation. Many coals require tempering, although no rule-of-thumb is possible as a guide in this respect. The heat release per foot of furnace width is most important. With a refractory furnace this figure may range up to 4 or 5 million Btu per hr and with a completely water-cooled furnace up to a million Btu.

Mr. Gilg stated that temperature in the cyclone runs over 3000 F with 7 to 10 per cent excess air, and that approximately 90 per cent of the ash in the coal is trapped in the molten slag. While this method of firing is best adapted to coal of relatively low ash-fusion temperature, he stated that coal of 2600 F ash-fusion temperature had been burned with high-temperature air. Volatile content is important to insure rapid combustion.

Smoke Control

At the first luncheon session, **H. G. Dyktor,** Commissioner of the Air Pollution Division for the City of Cleveland, stated the overall problem of atmospheric pollution control involves both social and engineering factors. The public sometimes expects the impossible and consideration must be given to industries in properly zoned sections that are cooperating and endeavoring to do as good a job as possible in avoiding a nuisance. Pollution, he pointed out, may result in part from certain industrial processes, from the combustion of fuel in power plants or apartments and also from traffic. It is important to determine the source and the extent of its contribution.

In Cleveland the ordinance is of the performance type without fuel restrictions, and it has not been necessary to resort to legal measures. When an offender refuses to cooperate it is usually sufficient to invite newspaper publicity with pictures. However, annual inspections of equipment are important.

Mr. Dyktor observed further that federal legislation has no place in smoke control; that the enforcement body should be independent of other city bureaus and that responsibility for enforcement should center in a single individual, rather than control boards. Cleveland, he said, spends annually between 18 and 19 cents per capita for atmospheric pollution control.

Today's Fuel Situation

Discussing the causes and probable effects of today's fuel situation, **H. A. Baldwin** of General Motors Corp. stressed the necessity of looking ahead as far as possible in view of the competitive struggle between coal, gas and oil. Coal is basic, because of its vast reserves, and the industry must be kept healthy. Although this industry for a long time had disregarded competition outside its own ranks, in recent years the increased cost of mining had resulted in a consolidation of its position to meet outside competition. He blamed the importation of foreign oil on the rising prices of coal, which had been due largely to increased labor cost, which constitutes about 60 per cent of the mining cost. On the other hand, oil is less sensitive to the labor factor.

Mr. Baldwin stated that natural gas reserves are sufficient for at least a generation and that each year the discovery of new reserves has exceeded the current use. Heavy oils, however, are a marginal product with gasoline demand dominating the supply.

Unless the coal industry can make a profit, there may be danger of it becoming nationalized, despite a strong feeling against subsidies or other government aid, which are not conducive to free enterprise. Therefore, the only alternative is to reduce production costs and combat competition by all means that will offer greater convenience to customers.

In the discussion of Mr. Baldwin's talk it was pointed out that he had ignored the developments made by Bituminous Coal Research; that large power customers are more generally buying coal at the lowest cost per million Btu; and that the present trend is toward use of the better grades of coal.

The Utility Problem

As the speaker at the banquet, **Elmer Lindseth,** president of the Cleveland

Electric Illuminating Co., reviewed the rôle of the electric utility industry in the present national situation. This 21-billion-dollar industry is the third largest in the country, ranked only by petroleum and railroads in terms of invested capital. Its present expansion program is the greatest in history and in the post-war period through 1953 it will have spent approximately 12 billion dollars in doubling its 1939 capacity. A conservative estimate indicates that the next 20 years will see a trebling of the present capacity.

Referring to the country's overall economic situation, Mr. Lindseth mentioned three possibilities that could disastrously strain our economy and destroy the very things for which we are fighting. These are:

1. A speculative boom.
2. A stagnation in our standard of living because of diversions that would produce unrest.
3. Tax rates so high as to stifle private enterprise.

Pointing out that there is at present $7\frac{1}{2}$ million kilowatts of government power plants under construction, he sensed a real hazard in the piecemeal socialization of the industry which the public is slow to realize. Moreover, too often regulation is dictated by prejudiced persons.

Following the talk by Mr. Lindseth, the "Percy Nicholls Award" was presented to Julian E. Tobey, president of Appalachian Coals, Inc., as an outstanding leader in the coal industry. Presentation was made by E. G. Bailey. This annual award is named in honor of the late Percy Nicholls, for many years supervising fuel engineer of the U. S. Bureau of Mines.

The banquet was also the occasion for presentation of a "Fifty Year ASME Membership Award" to John Rowland Brown, president of Reliance Gauge Column Co., and the grade of Fellow to William Mittendorf, of the Holmes-Darst Coal Corporation.

Papers presented on the second day of the meeting dealt more particularly with coal preparation, such as sampling at the mines, dewatering, flotation process and the results of an investigation into the abrasiveness of coal.

The speaker at the Wednesday luncheon was **George Whitwell,** vice president of the Philadelphia Electric Co., whose topic was "Competitive Aspects of the Utility Business." He declared that the ever-growing Federal power program is tending to force investor-owned utility companies out of business and that taxpayers in seventeen northeastern states are called upon to pay some 65 per cent of the cost of public power, whereas only 20 per cent of the total expense is borne by the areas served.

With regard to federally financed and controlled power plants, Mr. Whitwell stated that there are now in service 218 such stations totalling approximately $6\frac{3}{4}$ million kilowatts capacity, and that the planned future hydroelectric program alone involves 60 million kilowatts at an estimated cost of around 52 billion dollars. This is exclusive of the proposed St. Lawrence development, the R.E.A. and steam plants.

A.S.M.E. Annual Meeting Program Briefed

"THE Engineer and His Civic Responsibility" is the theme of the 1950 Annual Meeting of The American Society of Mechanical Engineers to be held at the Hotel Statler, New York, N. Y., November 27–December 1. This year the 19th National Power Show will be held in Grand Central Palace under A.S.M.E. auspices at the same time as the Annual Meeting.

Included on the technical program are 83 sessions and more than 225 papers covering essentially the mechanical engineering fields of power development, machine design and industrial management. In addition there will be a number of luncheon and dinner talks by outstanding speakers. At the President's Luncheon on Monday, November 27, A. W. Robertson, chairman of the board of the Westinghouse Electric Corporation will discuss "The Individual and Free Enterprise," while at the Gas Turbine Luncheon on Wednesday, November 29, George V. Denny, Jr., moderator of the Town Meeting of the Air, New York, will speak on "Public Events and Public Opinion." President James Cunningham of A.S.M.E. will preside at the Annual Dinner and honors night on Wednesday, November 29.

The following listing of papers and events is based upon the preliminary program. Since these arrangements are only tentative, persons planning to attend specific sessions will find it advisable to confirm dates and times by contacting A.S.M.E. Headquarters prior to the Annual Meeting.

Items of Interest in the Power Field

Monday, Nov. 27, 9:30 a.m.

"The Possibility of Balanced Flow in Compressor and Turbine Blading," by R. W. Pinnes, Bureau of Aeronautics, Washington, D. C.

"Influence of Reynolds Number on Performance of Turbomachinery," by A. M. G. Moody and Hunt Davis, Elliott Company, Jeannette, Pa., and M. D. Kottas, National Advisory Committee for Aeronautics, Cleveland, Ohio.

"A Study of the Mechanism of Boiling Heat Transfer," by Warren M. Rohsenow and John A. Clark, Massachusetts Institute of Technology, Cambridge, Mass.

Monday, Nov. 27, 2:30 p.m.

"Measured Performance of Pump Impellers," by W. C. Osborne and D. A. Morelli, California Institute of Technology, Pasadena, Calif.

"A Method for Calculating the Degree of Flow Deviation at the Discharge of Centrifugal-Pump Impellers," by W. C. Osborne, California Institute of Technology, Pasadena, Calif.

"Evaluation of the Quality of a Pump Impeller," by D. A. Morelli and J. H. Beveridge, California Institute of Technology, Pasadena, Calif.

Tuesday, Nov. 28, 9:30 a.m.

"Heat and Momentum Transfer Through Steam in Plain and Modified Annuli," by George W. Govier and Robert R. White, University of Michigan, Ann Arbor, Mich.

"Heat Transfer to a Fluid Flowing Turbulently in a Smooth Pipe With Walls at Constant Temperature," by R. A. Seban, University of California, Berkeley, Calif., and T. Shimazaki.

"The Precise Measurement of Temperature as an Aid to the Study of Heat Transfer," by H. Dean Baker, Columbia University, New York, N. Y., and E. A. Ryder, Pratt & Whitney Aircraft Division, United Aircraft Corp., Hartford, Conn.

Tuesday, Nov. 28, 12:15 p.m.—Power Luncheon

Presiding: Glenn B. Warren, General Electric Company, Schenectady, N. Y.

Tuesday, Nov. 28, 2:30 p.m.

"The Liquid-Coupled Indirect-Transfer Regenerator," by W. M. Kays and A. L. London, Stanford University, Stanford University, Calif.

"Optimum Design of Gas-Turbine Regenerators," by Warren M. Rohsenow, T. R. Yoas, and J. F. Brady, Massachusetts Institute of Technology, Cambridge, Mass.

Tuesday, Nov. 28, 8:00 p.m.

Panel: "Problems Encountered in Burning Heavy Fuel Oil as Related to Attack of Metals at High and Low Temperature and the Fouling of Tube Banks."

Speakers: O. L. Wood, Jr., General Electric Company, Schenectady, N. Y.; E. F. Tibbetts, The Lummus Company, New York, N. Y.; V. F. Estcourt, Pacific Gas and Electric Company, San Francisco, Calif.; Dwight Douglass, The Hartford Electric Light Company, Hartford, Conn.

Wednesday, Nov. 29, 9:30 a.m.

"Pressure and Residence Time Effects on Combustion of Pulverized Coal," by W. E. Young.

"Technical and Commercial Aspects of the Application of Residual Oil as Fuel for Gas Turbines and High-Temperature Boilers," by C. F. Kottcamp and L. O. Crockett, Gulf Oil Corporation, Pittsburgh, Pa.

"Power-Plant Operation With Hot Lime-Zeolite Process," by Louis F. Wirth, National Aluminate Corporation, Chicago, Ill., and William S. Butler, Dow Chemical Company, Ludington, Mich.

"Basic Study for a Generating Station," by G. R. Milne, Consolidated Edison Company of New York, Inc., New York, N. Y.

"Fireside Deposits of Steam Generators Minimized Through Humidification of Combustion Air," by Paul Murphy, Jr., John D. Piper, and C. R. Schmansky, The Detroit Edison Company, Detroit, Mich.

Wednesday, Nov. 29, 2:30 p.m.

"Review of Combustion Phenomena for the Gas Turbine," by D. G. Shepard, Cornell University, Ithaca, N. Y.

Furnace Heat Absorption in Pulverized-Coal-Fired Steam Generator, Willow Island Station:

Part I: "Furnace-Heat Absorption Efficiency as Shown by Temperature and Composition of Gases Leaving the Furnace," by James W. Myers and Richard C. Corey, Central Experiment Station, Bureau of Mines, Pittsburgh, Pa.

Part II: "Variation in Heat Absorption as Shown by Measurement of Surface Temperature of Exposed Side of Furnace Tubes," by F. G. Ely and N. H. Twyman, Babcock & Wilcox Company, Alliance, Ohio.

Thursday, Nov. 30, 9:30 a.m.

"Simplified Process for Determining Steam Purity," by S. T. Powell, consulting chemical engineer, Baltimore, Md., and I. G. McChesney, Rochester Gas and Electric Corporation, Rochester, N. Y.

"The Prevention of Embrittlement Cracking," by A. A. Berk, Bureau of Mines, College Park, Md.

"The Solubility of Quartz and Some Other Substances in Superheated Steam at High Pressures," by G. W. Morey, and J. M. Hesselgesser, Carnegie Institution of Washington, Washington, D. C.

"Strain Hardening and Softening With Time in Reference to Creep and Relaxation," by A. Nadai, Westinghouse Electric Corp., East Pittsburgh, Pa.

"Relaxation of Stress in a Heat-Exchanger Tube of Ideal Material," by E. A. Davis, Westinghouse Electric Corp., East Pittsburgh, Pa.

"Expanded Tube Joints in Feedwater Heaters and Heat Exchangers," by F. F. Fisher and G. F. Brown, Detroit Edison Company, Detroit, Mich.

"Analysis of Stresses and Displacements in Heat-Exchanger Expansion Joints," by G. Murphy, Iowa State College, Iowa City, Iowa.

Thursday, Nov. 30, 12:15 p.m.—Fuels Luncheon

Presiding: Elmer R. Kaiser, Bituminous Coal Research, Inc., Columbus, Ohio.
Speaker: Dr. James Boyd, Bureau of Mines, Washington, D. C.
Subject: Change in Patterns of Fuel Supply.

Thursday, Nov. 30, 2:30 p.m.

"Combination Spreader Stoker and Waste-Fuel Furnaces," by F. C. Messaros,

(Continued on page 66)

(Continued from page 65)

American Engineering Company, Philadelphia, Pa.

"Burning Petroleum Coke on Spreader Stokers" (motion picture), by Otto de Lorenzi, Combustion Engineering-Superheater, Inc., New York, N. Y.

"Stress and Deflection Tests of Steam-Turbine Diaphragm," by V. C. Taylor, Newport News Shipbuilding and Dry Dock Company, Newport News, Va.

"The Engineering of a 30,500-ton Super Tanker—the First Ship Using One Thousand and Twenty-Degree F Steam, by Lester M. Goldsmith, Atlantic Refining Company and Philadelphia Tankers, Inc., Philadelphia, Pa.

"Methods of Handling Coal at Today's Power Plants," by Frank Lovett, Link Belt Co., Chicago, Ill.

"Coal-Handling Installation at the Phillips Station, Wireton, Pa.," by E. M. Hays, Dravo Corporation, Pittsburgh, Pa.

Thursday, Nov. 30, 8:00 p.m.

"Analysis of Acoustical Oscillation in Burners," by A. R. Putnam, Battelle Memorial Institute, Columbus, Ohio.

"Effect of High-Frequency Sound Waves on Air-Propane Flame," by C. J. Kippenham, Washington University, St. Louis, Mo., and H. O. Croft, University of Missouri, Columbia, Mo.

"Recommended Practices for the Cleaning of Turbine Lubricating Systems After Service," prepared by Joint A.S.T.M.-A.S.M.E. Committee on Turbine Lubrication.

"An Investigation of the Role of Aluminum in the Graphitization of Plain Carbon Steel," by A. M. Hall and E. E. Fletcher, Battelle Memorial Institute, Columbus, Ohio.

"Creep and Creep-Rupture Testing of Steam-Boiler Materials," by J. B. Romer, The Babcock & Wilcox Co., Alliance, Ohio, and D. H. Newell, The Babcock & Wilcox Tube Company, Beaver Falls, Pa.

Friday, Dec., 1, 9:30 a.m.

"Effects of Internal Pressure on Stresses and Strains in Bolted Flanged Connections," by D. B. Wesstrom and S. E. Bergh, E. I. du Pont de Nemours & Company, Inc., Wilmington, Del.

"Formula for Pipe Thickness," by W. J. Buxton and W. R. Burrows, Whiting Refinery, Standard Oil Company (Indiana), Whiting, Ind.

"High-Temperature Properties and Characteristics of Ferritic Steam Piping," by A. W. Rankin and W. A. Reich. General Electric Company, Schenectady, N. Y.

"Report on Split Steam Lead at New Orleans, by A. W. Rankin and W. A. Reich, General Electric Company, Schenectady, N. Y.

"Intake Tunnel Design for Condenser Circulating Pumps," by A. I. Ponomareff, Westinghouse Electric Corporation, Lester, Pa.

Friday, Dec. 1, 2:30 p.m.

"Background of Present Smoke-Regulation Ordinances," by J. F. Barkley, Fuels Utilization Division, U. S. Bureau of Mines, Washington, D. C.

"Present Status of Air-Pollution Control," by H. P. Munger, Battelle Memorial Institute, Columbus, Ohio.

Items of General Interest

Monday, Nov. 27, 12:15 p.m.—President's Luncheon

Presiding: President James D. Cunningham, A.S.M.E.

Speaker: A. W. Robertson, Westinghouse Electric Corporation, Pittsburgh, Pa.

Subject: "The Individual and Free Enterprise."

Monday, Nov. 27, 8:00 p.m. Junior Session

A Plan for the First Five Years After Graduation:

"Community Relations," by Karl B. McEachron, Jr., General Electric Company, Schenectady, N. Y.

"Part-Time Graduate Studies," by J. C. McKeon, Westinghouse Electric Corporation, East Pittsburgh, Pa.

"Nontechnical Reading," by W. B. Embler, Cooper Union School of Engineering, New York, N. Y.

Tuesday, Nov. 28, 5:00 p.m.—Roy V. Wright Lecture

Wednesday, Nov. 29, 9:30 a.m.

"Planning Your Future," by T. A. Marshall, Jr., Metropolitan Life Insurance Company, New York, N. Y.

"What Industry Expects of and the Opportunities It Offers the Young Engineer in Our System of Free Enterprise," by Thomas C. Gary, E. I. du Pont de Nemours & Company, Inc., Wilmington, Del.

Wednesday, Nov. 29, 6:30 p.m.—Annual Dinner and Honors Night

Thursday, Nov. 30, 9:30 a.m.

Symposium on Fuel Engineering Education:

"What Engineering Schools Should Teach About Fuels and Fuel Utilization," by A. A. Potter, Purdue University, Lafayette, Ind.

"How Industry Can Co-Operate With and Assist Engineering and Technical Schools in Offering Instruction in Fuels and Fuel Utilization," by W. E. Reaser, Swarthmore College, Swarthmore, Pa.

"What Is Being Done Today on Instruction in Fuel Utilization for Engineering Schools?" by C. C. Wright, Pennsylvania State College, State College, Pa.

"On-the-Job Training Programs and Fuel Utilization," by R. J. Brandon, The Detroit Edison Company, Detroit, Mich.

High-Temperature Corrosion When Burning Some Oils

As is now well known, numerous severe cases of high-temperature corrosion of superheater spacers have occurred when burning some types of heavy fuel oil containing vanadium compounds. These have been associated with steam temperatures of 950 F and above in power plants and steam temperatures up to 1300 F in certain process work where the superheater tubes have also been attacked. The vanadium in the ash residue has been regarded as responsible either directly for the attack or indirectly as a catalyst.

Further light has been thrown on the subject by recent investigations at the Research Laboratory of International Nickel Company, as was reported in a paper by **E. N. Skinner** and **R. A. Kozlik** at the Petroleum Mechanical Engineering Conference in New Orleans, September 25–28. The results of these experiments led to the following conclusions:

1. That vanadium content and the copresence of alkali in the oil are primary factors; with temperature, metal composition and time of exposure as supplementary factors.
2. That at metal temperatures not exceeding 1200 F corrosion probably proceeds at a negligible rate due to the absence of molten constituents in the ash.
3. That pure vanadium pentoxide alone is a potent oxidation accelerant when in contact with certain alloys, particularly those containing significant amounts of molybdenum. Iron-chromium alloys of at least 25 per cent chromium and nickel-chromium-iron alloys with more than 50 per cent nickel and 14 per cent chromium were found to have suffered only negligible attack at metal temperatures even as high as 1500 F.
4. That vanadium pentoxide in combination with sodium sulfate accelerates scaling by promoting extensive sulfidation of the underlying metal. If the vanadium/sulfate ratio is small, the attack may be severe on alloys containing higher than about 30 per cent nickel. Under these conditions alloys with good resistance to sulfidation and low molybdenum content would be damaged to a lesser degree, whereas with a higher vanadium/sulfate ratio the reverse could be expected.

Energy Sales Continue to Increase

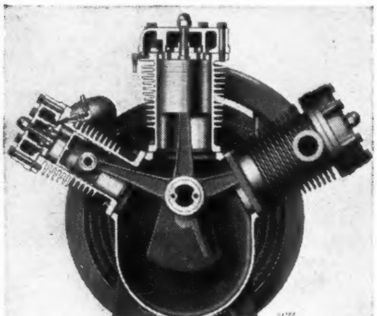
Sales of electric energy to ultimate consumers by electric utilities during August, as reported to the Federal Power Commission, exceeded 24,359,000 kwhr which was an increase of 14.2 per cent over August 1949. For the twelve months ending August 31, 1950, sales exceeded 272 million kilowatt-hours, which represented a 7.1 per cent margin over the preceding year. The greatest percentage increase was in sales to industrial consumers.

Peak loads attained a new maximum of over 55,316,000 kw in August of this year, which exceeded last December's peak of 54,238,000 kw.

NEW EQUIPMENT

Air Compressors

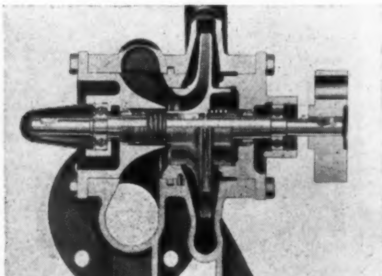
The Ingersoll-Rand Company, New York, N. Y., is offering two lines of their "T" series stationary air compressors. One of these lines is designed for normal industrial pressures of 100–125 psig, while the other is rated at 200 psig for continu-



ous service and up to 250 psig on intermittent pump-up service. Both types are available as tank-mounted, baseplate-mounted or bare units, with electric-motor or gasoline-engine drive. The units are air cooled by means of fan blades integrally cast on the fly wheel. Standard equipment includes a centrifugal unloader, intake filter and muffler and automatic start-and-stop control on tank-mounted and baseplate-mounted units.

General Service Pumps

De Laval Steam Turbine Co., Trenton, N. J., has designed a new line of small standardized general service pumps, all parts of which except the bare pump casing are contained in the rotor assembly. This arrangement is adaptable to a service



and exchange plan, for when maintenance is required it is merely necessary to remove the top cover and end plate studs, lift out the assembly and drop a new rotor in place. The new Type GS pump is built in three sizes for capacities to 450 gpm and heads to 230 ft.

Centrifugal Fan Ventilator

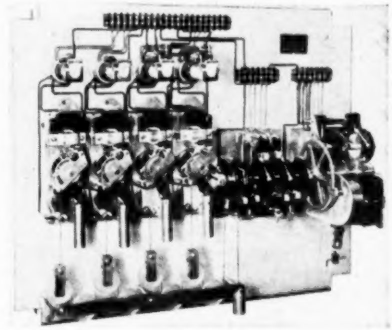
Especially suitable for situations where powered duct exhaust ventilators operating at very low noise levels are desirable is a new product of The Swartwout Company, Cleveland, Ohio, carrying the trade name "Airlift." The power unit features a centrifugal-type fan with backwardly curved blades, mounted within a weatherproof chamber. Welded steel framework provides sturdy support for the unit which may be furnished in 14 sizes, providing nearly 50 capacity variations.

Steam Trap

An inverted-bucket steam trap with a brass strainer built right into the body has been made available by the Armstrong Machine Works, Three Rivers, Mich. This side-inlet, side-outlet trap may be used for draining equipment producing relatively small amounts of condensate such as sterilizers, unit heaters and steam headers and risers. The built-in strainer feature eliminates separate strainer, extra fittings and installation labor.

Pump Control

Builders-Providence, Inc., Providence, R. I., has announced the availability of a new device for automatically controlling pump operation. Known as "Pressureflo" Control and developed from the original invention of M. C. Smith of the Richmond, Va., Department of Public Utilities, it con-



sists of a flow-determining means, a pressure or level sensing device and a mechanism to translate this information into a control function. This control may be used to start and stop pumps, to increase or decrease the speed of one or more pumps, to maintain a predetermined pressure at any point or to adjust automatically both pressure and flow to suit variable demands.

Business Notes

Edward Valves, Inc., East Chicago, Ind., has announced the following recent appointments and promotions in its organization: John E. Stevens, Jr., assistant to the president; Carl W. Nedderman, assistant vice president; Lawrence H. Carr, director of engineering and research; and Thomas E. Skilling, Pittsburgh district sales engineer.

Kinney Manufacturing Company, Boston, Mass., has appointed Kenneth Fox sales application engineer. He was formerly a vacuum metallurgist with National Research Corporation and in his new position will assist customers in the solution of problems involving use of vacuum.

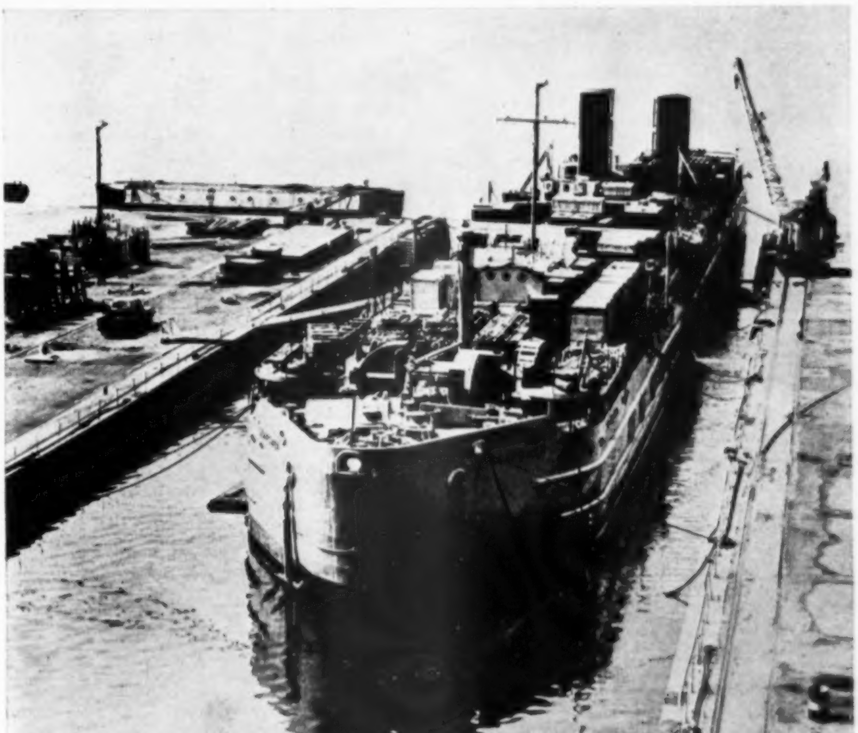
Warren Steam Pump Company, Warren, Mass., announces that Edward P. Doty, a well-known designer of screw and rotary pumps, has joined its organization.

E. F. Drew & Co., New York, has appointed Perry S. Lawrence as Southwest district manager covering sales and service in Texas, Arkansas, Oklahoma and Louisiana. It also announces appointment of James Quigley, James Devine and Charles T. Monroe as laboratory technicians in its Power Chemicals Division.

Aldrich Pump Company, Allentown, Pa., has appointed R. H. McPeake sales manager. A graduate of the U. S. Naval Academy, Mr. McPeake has had a number of years experience in oil field work followed by industrial engineering in South America.

Bailey Meter Company, Cleveland, O., has assigned five of its recent training course engineers to new branch office posts; they are: P. K. Bolyard to Atlanta; G. P. Dunegan to San Francisco; L. F. Monahan to Denver; R. E. Paulson to Kansas City, Mo.; and O. M. Thompson to Cincinnati.

Canadian Kellogg Ltd., has started operations in a new pipe fabricating shop in Edmonton, Alberta, according to an announcement by the parent company, The M. W. Kellogg Company, engineers and fabricators of New York and Jersey City. The shop, having an approximate monthly capacity of 400 tons, is equipped to fabricate not only carbon steel and low chrome piping, but also specialty materials such as stainless steel and high nickel alloys in a full range of pipe sizes.



Left—The floating steam-electric power generating plant, "Seapower," has been reconditioned under the supervision of Dravo Corp. for the Brazilian Traction, Light & Power Co., Ltd. The big vessel, originally built during World War II, supplied most of the electric power for rear echelon repair and supply depots at Ghent, Belgium. From 1946 until recently, it was operated at San Juan by the Puerto Rico Water Resources Authority. It can generate 30,000 kw, is 358 feet long and carries a staff of 58 men.

BOOKS

1—Steam Power Plants

By Philip J. Potter

503 pages Price $6.50

This addition to the list of college textbooks covering the heat-power field is characterized by an unusually detailed presentation of fundamental theory, without loss of practical attention to the present state of the power plant art. It also ranks among the best-illustrated books of its type, not only from the point of view of the selection of photographs, diagrams and curves, but also as an example of their excellent reproduction.

Following an introductory chapter the author undertakes an exposition of Flow of Fluids, a chapter which includes an especially intelligible discussion of viscosity along with practical data on piping. Then follow chapters on Pumps, Theory of Heat Transfer, Fuels and Combustion, Steam Generators, Boiler Auxiliaries, Heat-Exchangers, Steam Turbines, Steam Engines, Heat Balances and Economics of Steam Power Plants. Each chapter includes selected problems of the type encountered in power plant design and there is an appendix which contains two design problems on industrial power plant layouts along with typical dimensions and performance curves of representative equipment. The chapter on Steam Generators includes a 16-page account of boiler design, and theoretical considerations relative to steam turbines are discussed in more than usual detail in the chapter on Steam Turbines.

Practicing engineers will find Professor Potter's book a valuable addition to their technical library because it is well written and effectively illustrated.

2—Refresher Notes (Revised)

By John D. Constance

194 pages $8^3/_4 \times 11^1/_4$ Price $4.50

These notes, covering hydraulics, thermodynamics and machine design, form the basis of a tested course the author has given for several years past under the educational auspices of the Metropolitan Section A.S.M.E. Presenting the fundamental concepts, methods and applications of these subjects, the text is arranged as a review for those who have previously studied the subjects, and particularly to aid those who contemplate taking the examination for a professional engineer's license. In fact, most of the problems and their solutions are based on such past examination questions.

The book is in loose-leaf form, with paper cover, and the notes are offset. This revised edition contains a Mollier chart.

Each copy of the book will include solutions to a late New York State Professional Engineers' License examination covering the basic engineering sciences.

3—Fundamentals of Power Plant Engineering

By George E. Remp

347 pages $5^1/_2 \times 8^1/_2$ Price $6.50

The author, who is assistant professor of mechanical engineering at the University of Florida, has adopted a sequence of presentation that is quite different from that of most textbooks. Starting with a study of load curves, followed by the economics of power production, vapor power cycles and heat balances, he then proceeds to consideration of the various items of equipment that enter into a power plant. This logical approach simulates that which the student is likely to encounter later in practice. The treatment assumes familiarity with the fundamentals of engineering thermodynamics but is not too technical.

Numerous problems are included as well as their solutions, and the text is adequately illustrated. The appendix contains much useful data and a reproduction of the Combustion Engineering-Superheater steam tables.

4—Steam Turbines and Their Cycles

By J. Kenneth Salisbury

645 pages 6×9 Price $9.00

This subject has been dealt with in many texts, usually as part of textbooks written by professors with a view to acquainting undergraduate students with the fundamentals of power generation; but such information is obviously quite general. Of the very few authoritative treatises on the subject of steam turbines, such as the classic work of Stodola, most are now more or less out of date. In view of this the present contribution by Mr. Salisbury meets a widely felt need by providing an up-to-date, authoritative and practical volume that should be most useful to the practicing engineer.

A brief review of the contents reveals, among others, chapters on thermodynamics, power plant cycles, flow of liquids, turbine design and characteristics, cycle analysis, with particular reference to the regenerative cycle and heat balance, heater arrangements, design details, estimating heat rates, and various other factors affecting performance. The effect of many variables on plant performance is discussed at length. An appendix contains data often required by the application engineer in calculating heat balance.

5—Sales Engineering

Second Edition

By Bernard Lester

226 pages Price $3.00

Perhaps one of the least understood phases of engineering is that dealing with the sale of machinery, equipment and technical products. With the ever increasing use of "high-pressure" selling for consumer goods, it is natural to assume that industrial equipment is sold in a similar manner. However, Mr. Lester carefully differentiates methods applicable to each and points out that in sales engineering a successful sale is both a profitable sale to the supplier and a profitable purchase to the buyer.

There are five parts to the book: The Field of Sales Engineering, Buying and Selling, The Sales Engineer in Action, Selling to Those Who Buy for Resale and The Training and Development of the Sales Engineer.

The effectiveness of the text is enhanced by the skillful use of interesting case studies of actual industrial selling problems. Anyone who has been concerned with either buying or selling a major piece of power-plant equipment will recognize the practical usefulness and wisdom of the suggestions made in the case studies.

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